PB 184885

SYSTEMS STUDY FOR CONTROL OF EMISSIONS PRIMARY NONFERROUS SMELTING INDUSTRY

VOLUME II of III: APPENDICES A and B

FINAL REPORT UNDER CONTRACT PH 86-65-85

FOR
DIVISION OF PROCESS CONTROL ENGINEERING
NATIONAL AIR POLLUTION CONTROL ADMINISTRATION
PUBLIC HEALTH SERVICE
U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

JUNE 1969

ARTHUR G. McKEE & COMPANY
WESTERN KNAPP ENGINEERING DIVISION
SAN FRANCISCO, CALIFORNIA

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McKEE REPORT NO. 993

JUNE 1969

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SULFUR OXIDE EMISSIONS

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ABBREVIATIONS AND TECHNICAL TERMS

acfm	actual cubic feet per minute
Baume	a measure of liquid density used in specifying the strength of sulfuric acid. (66° Baume acid is 93.2% H_2SO_4)
Ip	initial investment of capital, capital cost
scf	standard cubic feet (caluculated to temperature of 32 F and pressure of one atmosphere.)
scfm	standard cubic feet per minute
sulfur equivalent	amount of sulfur required to produce a sulfur compound, such as sulfur dioxide or sulfuric acid. One ton of sulfur dioxide has a sulfur equivalent of 0.5005 tons; one ton of sulfuric acid has a sulfur equivalent of 0.3270 tons.
Volume %	volumes of the named constituent gas per 100 volumes of the whole gas

Chemical symbols used:

CO_2	carbon dioxide
Cu	copper
H_2O	water
H_2SO_4	sulfuric acid
N_2	molecular nitrogen
O_2	molecular oxygen
Pb	lead
S	sulfur
SO_2	sulfur dioxide
SO_3	sulfur trioxide
Zn	zinc

SUMMARY - CURRENT SULFUR OXIDE EMISSION RATES AND EXTENT OF CONTROL - COPPE

Thousands of Short Tons per Year

Plant Code No.	Operating Days per Year	Estimated Capacity for Copper Production	Sulfur Equivalent of Sulfu			
			Generated in			Total Generate
			Roasters	Reverbs	Converters	
East of Mississippi						
326.16	365	84	0	3.7	29.5	33.2
.30	350	16	16.1	1.8	11.2	29.1
Total eastern		100				62.3
West of Mississippi						
326.01	362	72	26.8	13.4	40.9	81.1
.02	358	91	0	22.9	53.3	76.2
.03	358	72	58.0	9.0	47.6	114.6
.04	312	23	0	15.8	21.1	36.9
.05	365	105	139.4	48.2	84.0	271.6
.06	365	157	69.0	55.8	116.8	241.6
.07	339	75	0	18.3	49.2	67.5
.08	357	102	0	24.3	89.2	113.5
.20	358	141	0	32.6	83.4	116.0
.22	300	39	0	27.0	52.5	79.5
.24	365	110	0	28.8	76.7	105.5
.33	365	120	30.7	12.8	49.6	93.1
.35	365	332	0	68.3	227.0	295.3
.36	300	79	20.1	8.4	32.7	61.2
Total western		1,518				1,753.6
Total U.S.		1,618				1,815.9(1)

* * * *

Planned 1970 production - western						
326.35	365	332	0	29.6	266.4	296.0
Total 1970 western		1,518				1,754.3
Total 1970 U.S.		1,618				1,816.6(1)

(1) These figures do not include sulfur oxides generated in the roasting of iron pyrites for sulfuric acid production.

(2) All recovered as sulfuric acid.

Appendix A
Table A - 1

UMMARY - CURRENT SULFUR OXIDE EMISSION RATES AND EXTENT OF CONTROL - COPPER SMELTERS

Thousands of Short Tons per Year

ping er	Estimated Capacity for Copper Production	Sulfur Equivalent of Sulfur Oxides: Generated in Roasters	Reverbs	Converters	Total Generated	Recovered	Vented to Atmosphere
pi							
	84	0	3.7	29.5	33.2	0	33.2
	16	16.1	1.8	11.2	29.1	26.3	2.8
	100				62.3	26.3	36.0
pi							
	72	26.8	13.4	40.9	81.1	0	81.1
	91	0	22.9	53.3	76.2	0	76.2
	72	58.0	9.0	47.6	114.6	85.9	28.7
	23	0	15.8	21.1	36.9	0	36.9
	105	139.4	48.2	84.0	271.6	0	271.6
	157	69.0	55.8	116.8	241.6	56.6	185.0
	75	0	18.3	49.2	67.5	0	67.5
	102	0	24.3	89.2	113.5	0	113.5
	141	0	32.6	83.4	116.0	0	116.0
	39	0	27.0	52.5	79.5	0	79.5
	110	0	28.8	76.7	105.5	0	105.5
	120	30.7	12.8	49.6	93.1	0	93.1
	332	0	68.3	227.0	295.3	161.0	134.3
	79	20.1	8.4	32.7	61.2	14.4	46.8
	1,518				1,753.6	317.9	1,435.7
	1,618				1,815.9(1)	344.2(1,2)	1,471.7(1)
*	*		*		*	*	
tion - western							
	332	0	29.6	266.4	296.0	208.8	87.2
	1,518				1,754.3	365.7	1,388.6
	1,618				1,816.6(1)	392.0(1,2)	1,424.6(1)

do not include sulfur oxides generated in the
on pyrites for sulfuric acid production.

as sulfuric acid.

B

SUMMARY - CURRENT SULFUR OXIDE EMISSION RATES AND EXTENT OF CONTROL - ZIN

Thousands of Short Tons per Year

Plant Code No.	Operating Days per Year	Estimated Capacity for Zinc Production	Sulfur Equivalent of Sulf			
			Generated in			
			Roasters	Sintering Machines	Cokers & Retorts	Total Generate
East of Mississippi						
326.12	365	88	49.9	--(3)	--(3	49.9
.14	350	88	50.1	0.2	0.6	50.9
.28	365	215	124.	4.4	neg.	128.4
.29	350	105	58.7	1.3	.8	60.8
.37	360	47	preroasted feed		.1	.1
Total eastern		543				290.1
West of Mississippi						
326.10	365	252	159.0	--(3)	--(3)	159.0
.15	330	59	33.6	0	.6	34.2
.20	301	92	52.1	--(3)	--(3)	52.1
.21	365	116	66.0	--(3)	--(3)	66.0
.25	330	92	0	60.1	neg.	60.1
.26	150	--(1)	preroasted feed		.2	.2
.27	350	44	23.4	3.2	neg.	26.6
.31	365	53	27.0	5.8	neg.	32.8
.32	365	56	26.5	7.8	.3	34.6
.38	350	45	27.0	--(3)	--(3)	27.0
Total western		809				492.6
Total U.S.		1,352				782.7(2

neg. = negligible

(1) Secondary plant. Zinc production capacity is included elsewhere.

(2) At one or more smelters, elemental sulfur is burned solely for the purpose of making more sulfuric acid. These figures do not include sulfur oxides emitted, recovered, or vented in acid plant tail gases as a result of such burning of sulfur.

(3) The calcine from the ro
an electrolytic plant
Sintering machines, c
are not used.

Appendix A
Table A - 2

MARY - CURRENT SULFUR OXIDE EMISSION RATES AND EXTENT OF CONTROL - ZINC SMELTERS

Thousands of Short Tons per Year

Estimated Capacity for Zinc Production	Sulfur Equivalent of Sulfur Oxides: Generated in: Roasters	Sintering Machines	Cokers & Retorts	Total Generated	Recovered	Vented to Atmosphere
88	49.9	--(3)	--(3	49.9	48.9	1.0
88	50.1	0.2	0.6	50.9	49.2	1.7
215	124.	4.4	neg.	128.4	121.2	7.2
105	58.7	1.3	.8	60.8	56.9	3.9
47	preroasted feed		.1	.1	0	.1
543				290.1	276.2	13.9
252	159.0	--(3)	--(3)	159.0	78.2	80.8
59	33.6	0	.6	34.2	32.3	1.9
92	52.1	--(3)	--(3)	52.1	26.8	25.3
116	66.0	--(3)	--(3)	66.0	0	66.0
92	0	60.1	neg.	60.1	0	60.1
--(1)	preroasted feed		.2	.2	0	.2
44	23.4	3.2	neg.	26.6	21.8	4.8
53	27.0	5.8	neg.	32.8	0	32.8
56	26.5	7.8	.3	34.6	0	34.6
45	27.0	--(3)	--(3)	27.0	26.3	.7
809				492.6	185.4	307.2
1,352				782.7(2)	461.6(2)	321.1(2)

. Zinc production capacity
lsewhere.

smelters, elemental sulfur
ely for the purpose of making
acid. These figures do not
r oxides emitted, recovered,
acid plant tail gases as a
h burning of sulfur.

(3) The calcine from the roaster goes to an electrolytic plant for zinc recovery. Sintering machines, cokers, or retorts are not used.

B

SUMMARY - CURRENT SULFUR OXIDE EMISSION RATES AND EXTENT OF CONTROL - L

Thousands of Short Tons per Year

Plant Code No.	Operating Days per Year	Estimated Capacity for Lead Production	Sulfur Equivalent of			
			Generated in			
			Sintering Machines	Blast Furnaces	Other	T Gen
West of Mississippi						
326.09	365	76	19.2	0.5	0.2	
.10	348	122	36.2	.2	.4	
.17	360	198	39.1	.4	neg.	
.18	365	120	28.5	.2	neg.	2
.19 (3)	365	--	0	0	1.8	
.33	365	91	33.8	.7	1.1 (1)	3
.34	260	42	13.5	1.0	1.9	1
Total western		649				17
Total U.S.		649				17

neg. = negligible

(1) Additional minor quantity not reported or estimated.

(2) Approximately 4.6 thousand tons of this total is recovered as liquid sulfur dioxide, all the rest as sulfuric acid.

(3) This is a slag fuming plant, not a complete smelter.

A

Appendix A
Table A - 3

SUMMARY - CURRENT SULFUR OXIDE EMISSION RATES AND EXTENT OF CONTROL - LEAD SMELTERS

Thousands of Short Tons per Year

		Sulfur Equivalent of Sulfur Oxides:					
		Generated in					
rating s per ear	Estimated Capacity for Lead Production	Sintering Machines	Blast Furnaces	Other	Total Generated	Recovered	Vented to Atmosphere
sippi							
365	76	19.2	0.5	0.2	19.9	9.3	10.6
348	122	36.2	.2	.4	36.8	0	36.8
360	198	39.1	.4	neg.	39.5	37.8	1.7
365	120	28.5	.2	neg.	28.7	0	28.7
365	--	0	0	1.8	1.8	0	1.8
365	91	33.8	.7	1.1 (1)	35.6	0	35.6
260	42	13.5	1.0	1.9	16.4	0	16.4
	649				178.7	47.1	131.6
	649				178.7	47.1 (2)	131.6

ible

minor quantity not reported
ated.

ely 4.6 thousand tons of this
recovered as liquid sulfur
all the rest as sulfuric acid.

slag fuming plant, not a
smelter.

B

GAS FLOWS AND COMPOSITIONS

Plant Code No.	Gas Source or Point of Measurement	Duration of flow, hr	Temperature °F	Volum thous scf
326.01	Roaster	24	1200	9.
	Reverb	24	2300	28.
	Per converter (total of two):			
	Slag blow	11.6	2300	17.
	Finish blow	3.8	2200	21.
	Stacks (two)			
	Roaster & reverb	24	250	250.
	Converter	24 av	450	100.
326.02	Reverb	24	2300	40.5
	Converter blows			
	2 slag, 1 finish	12	2250	16.7
	2 slag	4	2300	10.6
	1 slag, 1 finish	8	2200	11.4
	Stacks (two)			
	Reverb	24 av	315	285
	Converter	24 av	300	240
326.03	Roaster	24	1200	16.8
	Reverb	24	2300	53.6
	Converter blows			
	1 slag	14	2300	8.0
	2 slag	3	2300	16.0
	1 slag, 1 finish	7	2250	22.4
	Stack (one)			
	Reverb only	10	600	142.0
	Reverb & converter	14	550	371.0
	Gas to acid plant			
	Roaster only, av	7	550	87.0
	Roaster & converter, av	17	550	51.9
326.04	Reverb	24	2200	26.2
	Converter blows			
	1 slag	16	2200	6.2
	1 finish	4	2200	9.3
	No blow	4		0
	Stack (one)	24	300	250.0

(continued on next sheet)

A

Appendix A
Table A-4
Sheet 1 of 4

OWS AND COMPOSITIONS - COPPER SMELTERS

Temperature °F	Volume, thousand scfm	Composition, volume percent					
		SO_2	SO_3	O_2	CO_2	H_2O	N_2
1200	9.5	12.1	N.R.	N.R.	N.R.	N.R.	N.R.
2300	28.4	2.1	N.R.	N.R.	N.R.	N.R.	N.R.
2300	17.2	14.2	N.R.	0.5	nil	nil	85
2200	21.3	18.9	N.R.	2	nil	nil	79
250	250.	.69	N.R.	N.R.	N.R.	N.R.	N.R.
450	100.	1.75	N.R.	20	N.R.	N.R.	78
2300	40.5	2.45	N.R.	N.R.	N.R.	N.R.	N.R.
2250	16.7	16.7	N.R.	1	nil	neg.	82
2300	10.6	15.0	N.R.	1	nil	neg.	84
2200	11.4	17.4	N.R.	2	nil	neg.	80
315	285	.35	N.R.	N.R.	N.R.	N.R.	N.R.
300	240	.97	N.R.	19	N.R.	N.R.	79.
1200	16.8	15.0	N.R.	N.R.	N.R.	N.R.	N.R.
2300	53.6	.73	N.R.	N.R.	N.R.	N.R.	N.R.
2300	8.0	14.2	N.R.	1	nil	nil	84
2300	16.0	14.2	N.R.	1	nil	nil	84
2250	22.4	17.2	N.R.	1	nil	nil	80
600	142.0	.28	N.R.	N.R.	N.R.	N.R.	N.R.
550	371.0	.41	N.R.	N.R.	N.R.	N.R.	N.R.
550	87.0	8.4	N.R.	N.R.	N.R.	N.R.	N.R.
550	51.9	4.9	N.R.	N.R.	N.R.	N.R.	N.R.
2200	26.2	2.6	N.R.	N.R.	N.R.	N.R.	N.R.
2200	6.2	15.0	N.R.	neg.	nil	nil	84
2200	9.3 0	18.9	N.R.	neg.	nil	nil	80
300	250.0	.64	N.R.	N.R.	N.R.	N.R.	N.R.

B

Plant Code No.	Gas Source or Point of Measurement	Duration of flow, hr	Temperature °F	Volume, thousand scfm
326.05	Roaster	24	1350	139.0
	Reverb	24	2200	83.2
	Converter blows			
	2 slag	10.1	2300	27.7
	1 slag	4.3	2300	13.9
	1 finish	3.8	2200	15.0
	1 slag, 1 finish	5.8	2250	28.9
	Stacks (two)			
	Roaster & reverb	24	390	437.0
	Converter	24	350	240.0 av
326.06	Roaster	24	1200	24.6
	Reverb	24	2400	155.0
	Converter blows			
	2 slag, 1 finish	12	2200	36.7
	3 slag	12	2200	27.8
	Stack	24	N.R.	368.0
	Acid plant			
	Feed	24	N.R.	N.R.
	Tail gas	24	180	40.2
326.07	Reverb	24	2500	40.5
	Converter blows			
	1 slag, 1 finish	2.8	2275	25.4
	1 slag	14.8	2275	13.5
	1 finish	6.4	2225	11.9
	Stack (one)	24	350	310.0 av
326.08	Reverb	24	1800	53.7
	Converter blows			
	2 slag	6	2250	34.1
	1 slag	10	2250	17.0
	1 finish	2	2250	17.0
	1 slag, 1 finish	6	2250	34.1
	Stack (one)	24	350	300.0 av
326.16	Reverb	24	2600	51.1
	Converter blows			
	1 slag	2.2	2300	24.0
	1 finish	9.5	2250	12.8
	Idle	12.3	N.R.	1.8
	Stack (one)	24	400	200. av

(continued on next sheet)

Appendix A
Table A-4
Sheet 2 of 4

Temperature °F	Volume, thousand scfm	Composition, volume percent					
		SO_2	SO_3	O_2	CO_2	H_2O	N_2
1350	139.0	4.3	N.R.	N.R.	N.R.	N.R.	N.R.
2200	83.2	2.5	N.R.	N.R.	N.R.	N.R.	N.R.
2300	27.7	14.1	N.R.	1	nil	neg.	84
2300	13.9	14.0	N.R.	1	nil	neg.	84
2200	15.0	18.7	N.R.	1	nil	neg.	80
2250	28.9	16.5	N.R.	1	nil	neg.	82
390	437.0	1.8	N.R.	N.R.	N.R.	N.R.	N.R.
350	240.0 av	1.5	N.R.	N.R.	N.R.	N.R.	N.R.
1200	24.6	11.9	N.R.	N.R.	N.R.	N.R.	N.R.
2400	155.0	1.5	.2	3.3	9.2	10.0	75.6
2200	36.7	16.4	N.R.	1	neg.	neg.	82.0
2200	27.8	14.1	N.R.	1	neg.	neg.	84.0
N.R.	368.0	2.0	N.R.	N.R.	N.R.	N.R.	N.R.
N.R.	N.R.	8.0	.4	N.R.	N.R.	N.R.	N.R.
180	40.2	1.3	N.R.	N.R.	N.R.	N.R.	N.R.
2500	40.5	2.1	N.R.	neg.	11	N.R.	N.R.
2275	25.4	16.4	N.R.	1	neg.	neg.	82
2275	13.5	14.1	N.R.	1	neg.	neg.	84
2225	11.9	19.0	N.R.	1	neg.	neg.	80
350	310.0 av	1.0	N.R.	N.R.	N.R.	N.R.	N.R.
1800	53.7	2.0	N.R.	.5	N.R.	N.R.	N.R.
2250	34.1	14.2	N.R.	1	neg.	neg.	84
2250	17.0	14.2	N.R.	1	neg.	neg.	84
2250	17.0	18.9	N.R.	2	neg.	neg.	80
2250	34.1	16.5	N.R.	1	neg.	neg.	82
350	300.0 av	1.6	N.R.	N.R.	N.R.	N.R.	N.R.
2600	51.1	.3	N.R.	neg.	N.R.	N.R.	N.R.
2300	24.0	14.1	N.R.	1	nil	nil	84
2250	12.8	18.6	N.R.	2	nil	nil	79
N.R.	1.8	neg.	N.R.	N.R.	N.R.	N.R.	N.R.
400	200. av	.7	N.R.	N.R.	N.R.	N.R.	N.R.

B

Plant Code No.	Gas Source or Point of Measurement	Duration of flow, hr	Temperature °F	Volume, thousand scfm
326.20	Dryer	24	400	11.0
	Reverb	24	1100	79.1
	Converter blows			
	1 slag, 1 finish	12.6	2200	19.9
	2 slag	5.7	2200	18.9
	2 slag, 1 finish	5.7	2200	29.0
	Stack (one)	24	350	323.0 av
326.22	Reverb	24	2250	45.5
	Converter blows			
	1 slag, 1 finish	2.6	2250	25.0
	2 slag	9.4	2300	24.2
	1 slag	9.4	2300	12.1
	1 finish	2.6	2200	12.9
	Stacks (two)			
	Reverb	24	350	81.6
	Converter	24	350	100.0 av
326.24	Reverb	24	2800	46.5
	Converter blows			
	1 slag, 1 finish	12	2150	22.7
	1 slag	12	2150	10.2
	Stacks (two)			
	Reverb	24	450	65.7 av
	Converter	24	650	125.0 av
326.30	Roaster	24	N.R.	6.0
	Reverb	24	N.R.	27.0
	Converter blows			
	slag	9	2300	12.0
	Finish	6	2200	12.0
	Acid plant feed	24	N.R.	N.R.
	Tail gas	24	N.R.	N.R.
	Stack (one)	24	900	N.R.
326.33	Roaster	24	N.R.	N.R.
	Reverb	24	N.R.	33.5
	Converter (av)	24	N.R.	N.R.
	Stack (one)	24	350	166.

(concluded on next sheet)

Appendix A
Table A-4
Sheet 3 of 4

Temperature °F	Volume, thousand scfm	Composition, volume percent					
		SO_2	SO_3	O_2	CO_2	H_2O	N_2
400	11.0	nil	nil	N.R.	N.R.	N.R.	N.R.
1100	79.1	1.8	N.R.	N.R.	N.R.	N.R.	N.R.
2200	19.9	17.3	N.R.	1	neg.	neg.	81
2200	18.9	14.9	N.R.	1	neg.	neg.	84
2200	29.0	16.7	N.R.	1	neg.	neg.	82
350	323.0 av	1.6	N.R.	N.R.	N.R.	N.R.	N.R.
2250	45.5	3.1	N.R.	N.R.	N.R.	N.R.	N.R.
2250	25.0	16.5	N.R.	1	nil	nil	82
2300	24.2	14.1	N.R.	1	nil	nil	84
2300	12.1	14.2	N.R.	1	nil	nil	84
2200	12.9	18.9	N.R.	2	nil	nil	79
350	81.6	1.7	N.R.	N.R.	N.R.	N.R.	N.R.
350	100.0 av	2.7	N.R.	N.R.	N.R.	N.R.	N.R.
2800	46.5	2.6	N.R.	2.0	8.3	19	67.8
2150	22.7	19.6	N.R.	N.R.	N.R.	N.R.	N.R.
2150	10.2	20.6	N.R.	N.R.	N.R.	N.R.	N.R.
450	65.7 av	1.9	N.R.	N.R.	N.R.	N.R.	N.R.
650	125.0 av	2.6	N.R.	N.R.	N.R.	N.R.	N.R.
N.R.	6.0	15.3	neg.	nil	nil	neg.	84.6
N.R.	27.0	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
2300	12.0	14.2	N.R.	1	nil	nil	84
2200	12.0	18.9	N.R.	2	nil	nil	79
N.R.	N.R.	7.5	N.R.	N.R.	N.R.	N.R.	N.R.
N.R.	N.R.	.3	N.R.	N.R.	N.R.	N.R.	N.R.
900	N.R.	.4	N.R.	12.5	6.4	4.0	76.7
N.R.	N.R.	N.R.	N.R.	neg.	N.R.	N.R.	N.R.
N.R.	33.5	1.6	N.R.	neg.	N.R.	N.R.	N.R.
N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
350	166.	2.4	N.R.	N.R.	N.R.	N.R.	N.R.

B

Plant Code No.		Gas Source or Point of Measurement	Duration of flow, hr	Temperature °F	Volume, thousand scfm
326.35	(1968)	Reverb	24	2800	165.0
		Converter blows*			
		2 slag, 2 finish	12	2250	66.1
		2 slag, 1 finish	12	2250	53.6
		Stacks (two)			
		Average	24	350	212.0
		Acid plant feed (av)	24	350	136.0
326.35	(1970)	Reverb	24	2800	79.4
		Converter blows**			
		2 slag, 2 finish	12	2250	64.1
		2 slag, 1 finish	12	2250	52.1
		Stacks (two)			
		Average	24	350	113.0
		Acid plant feed	24	350	156.0
326.36		Roaster	24	N.R.	N.R.
		Reverb	24	N.R.	N.R.
		Converter (av)	24	N.R.	N.R.
		Acid plant			
		Feed	24	N.R.	N.R.
		Tail gas	24	N.R.	N.R.
		Stack (one)	24	N.R.	N.R.

Notes:

Gases from roasting of pyrites for sulfuric acid production are not re

N.R. - Not reported

nil - Insignificant quantity

neg. - Minor quantity present, but not reported or estimated

* - Oxygen enrichment on one converter

** - Oxygen enrichment on all converter slag blows

Appendix A
Table A - 4
Sheet 4 of 4

Temperature °F	Volume, thousand scfm	Composition, volume percent					
		SO_2	SO_3	O_2	CO_2	H_2O	N_2
2800	165.0	1.8	N.R.	2.2	7.5	20.2	68.3
2250	66.1	16.4	N.R.	N.R.	N.R.	N.R.	82
2250	53.6	15.8	N.R.	N.R.	N.R.	N.R.	82
350	212.0	2.5	N.R.	N.R.	N.R.	N.R.	N.R.
350	136.0	5.3	N.R.	N.R.	N.R.	N.R.	N.R.
2800	79.4	1.6	N.R.	2.4	7.5	20.2	68.3
2250	64.1	19.6	N.R.	N.R.	N.R.	N.R.	N.R.
2250	52.1	19.5	N.R.	N.R.	N.R.	N.R.	N.R.
350	113.0	2.9	N.R.	N.R.	N.R.	N.R.	N.R.
350	156.0	6.0	N.R.	N.R.	N.R.	N.R.	N.R.
N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
N.R.	N.R.	1.6	N.R.	N.R.	N.R.	N.R.	N.R.
N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
N.R.	N.R.	2.4	N.R.	N.R.	N.R.	N.R.	N.R.

ric acid production are not reported in this table.

rter

rter slag blows

B

GAS FLOWS AND COMPOSITIONS - ZINC SM

Plant Code No.	Gas Source or Point of Measurement	Temperature °F	Volume, thousand scfm	Com
				SO_2
326.10	Roaster	1600	94.5	6.9
	Acid plant feed	300	47.6	6.9
	Acid plant tail gas	180	42.	.2
	Bypass stack	300	46.9	6.9
326.12	Roaster	1600	32.0	6.3
	Acid plant tail gas	180	27.7	.16
326.14	Dryer	250	3.6	nil
	Roaster	1900	22.2	10.0
	Sinter machine	400	23.2	.05
	Coker	N.R.	N.R.	nil
	Acid plant tail gas	160	29.0	.14
	100-ft stack	130	23.2	.05
	130-ft stack	N.R.	N.R.	nil
326.15	Roaster	2000	16.	9.6
	Acid plant tail gas	180	19.	.3
	Nodulizing kiln stack	300	6.	.5
326.20	Roaster	N.R.	23.	11.3
	Acid plant tail gas	180	14.	1.1
	Stack	N.R.	33.(1)	4.
326.21	Stack	400	380.	.74
326.25	Sintering stack	200	150.	2.
	Furnace stack	N.R.	N.R.	nil
	Cadmium plant stack	N.R.	N.R.	nil
326.26	Furnace stack	N.R.	N.R.	N.R.
	Waelz kiln stack	170	40.	.02
326.27	Roaster	1200	9.5	10.8
	Acid plant tail gas	250	12.	.6
	150-ft stack	160	32.	.5

(concluded on next sheet)

Appendix A
Table A - 5
Sheet 1 of 2

GAS FLOWS AND COMPOSITIONS - ZINC SMELTERS

e or surement	Temperature ^oF	Volume, thousand scfm	Composition, volume percent SO_2	SO_3	O_2	CO_2	H_2O	N_2
	1600	94.5	6.9	0.3	10	nil	4	79
eed	300	47.6	6.9	.3	10	nil	4	79
il gas	180	42.	.2	nil	9	nil	nil	91
	300	46.9	6.9	.3	10	nil	4	79
	1600	32.0	6.3	.3	11	neg.	3	79
il gas	180	27.7	.16	nil	10	neg.	nil	90
	250	3.6	nil	nil	1	4	61	34
	1900	22.2	10.0	N.R.	6	nil	3	81
e	400	23.2	.05	nil	N.R.	N.R.	N.R.	N.R.
	N.R.	N.R.	nil	nil	N.R.	N.R.	N.R.	N.R.
il gas	160	29.0	.14	nil	9	N.R.	nil	91
	130	23.2	.05	nil	N.R.	N.R.	N.R.	N.R.
	N.R.	N.R.	nil	nil	N.R.	N.R.	N.R.	N.R.
	2000	16.	9.6	.4	N.R.	N.R.	N.R.	N.R.
il gas	180	19.	.3	nil	10	neg.	nil	90
ln stack	300	6.	.5	nil	N.R.	N.R.	nil	N.R.
	N.R.	23.	11.3	.4	N.R.	N.R.	N.R.	N.R.
il gas	180	14.	1.1	nil	N.R.	N.R.	nil	N.R.
	N.R.	33.(1)	4.	.1	N.R.	N.R.	N.R.	N.R.
	400	380.	.74	nil	13	5	10	72
ck	200	150.	2.	neg.	N.R.	N.R.	N.R.	N.R.
	N.R.	N.R.	nil	nil	N.R.	N.R.	N.R.	N.R.
stack	N.R.	N.R.	nil	nil	N.R.	N.R.	N.R.	N.R.
	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
ack	170	40.	.02	nil	N.R.	N.R.	N.R.	N.R.
	1200	9.5	10.8	.2	6	neg.	neg.	83
l gas	250	12.	.6	nil	5	neg.	nil	95
	160	32.	.5	nil	N.R.	N.R.	N.R.	N.R.

next sheet)

B

Plant Code No.	Gas Source or Point of Measurement	Temperature °F	Volume, thousand scfm	Compositi	
				SO_2	SO_3
326.28	Roaster	1600	19.3	10.6	0.4
	Roaster	1800	4.6	12.6	.5
	Roaster	1650	19.8	12.5	.5
	Sinter machine	400	58.5	.32	nil
	Zinc oxide furnace	N.R.	N.R.	nil	nil
	Acid plant tail gas	180	78.0	.15	nil
	Three stacks	130	N.R.	nil	nil
	Main stacks	140	328. (1)	.09	nil
326.29	Roaster	1800	23.8	10.6	.4
	Waelz kiln	1100	240.	.004	nil
	Coker	1800	N.R.	neg.	nil
	Acid plant tail gas	180	35.0	.22	nil
	Waelz stack	300	30.0	.003	nil
	Sintering stack	160	135.	.04	nil
	Stack	N.R.	N.R.	neg.	nil
326.31	Dryer	N.R.	6.	nil	nil
	Roaster	700	123.	.94	neg.
	Sinter machine	200	95.	.26	nil
	Stack	500	224.	.62	neg.
	Furnace stack	N.R.	N.R.	nil	nil
326.32	Roaster	900	166.	.7	.1
	Sinter machine	300	22.2	1.4	.1
	Furnace	N.R.	N.R.	neg.	nil
	Dryer stack	N.R.	N.R.	nil	nil
	Roaster stacks	800	166.	.7	.1
	150-ft stack	N.R.	N.R.	N.R.	nil
326.37	Coker stack	900	20.	.02	nil
	Retort stack	1300	38.	nil	nil
326.38	Roaster	N.R.	N.R.	N.R.	N.R.
	Acid plant tail gas	180	8.	.4	nil

Notes:

Gases from burning of sulfur for sulfuric acid production are not reported in this table.

(1) Includes acid plant tail gas

N.R. - Not reported

nil - Insignificant quantity

neg. - Minor quantity present, but not reported or estimated

Appendix A
Table A-5
Sheet 2 of 2

or rement	Temperature °F	Volume, thousand scfm	Composition, volume percent SO_2	SO_3	O_2	CO_2	H_2O	N_2
	1600	19.3	10.6	0.4	N.R.	nil	N.R.	N.R.
	1800	4.6	12.6	.5	N.R.	nil	N.R.	N.R.
	1650	19.8	12.5	.5	N.R.	nil	N.R.	N.R.
	400	58.5	.32	nil	N.R.	N.R.	N.R.	N.R.
ace	N.R.	N.R.	nil	nil	N.R.	N.R.	N.R.	N.R.
gas	180	78.0	.15	nil	N.R.	N.R.	N.R.	N.R.
	130	N.R.	nil	nil	N.R.	N.R.	nil	N.R.
	140	328. (1)	.09	nil	N.R.	N.R.	N.R.	N.R.
	1800	23.8	10.6	.4	N.R.	N.R.	N.R.	N.R.
	1100	240.	.004	nil	N.R.	N.R.	N.R.	N.R.
	1800	N.R.	neg.	nil	N.R.	N.R.	N.R.	N.R.
gas	180	35.0	.22	nil	N.R.	N.R.	nil	N.R.
	300	30.0	.003	nil	N.R.	N.R.	N.R.	N.R.
	160	135.	.04	nil	N.R.	N.R.	N.R.	N.R.
	N.R.	N.R.	neg.	nil	N.R.	N.R.	N.R.	N.R.
	N.R.	6.	nil	nil	N.R.	N.R.	N.R.	N.R.
	700	123.	.94	neg.	N.R.	N.R.	neg.	N.R.
	200	95.	.26	nil	N.R.	N.R.	neg.	N.R.
	500	224.	.62	neg.	N.R.	N.R.	N.R.	N.R.
	N.R.	N.R.	nil	nil	N.R.	N.R.	N.R.	N.R.
	900	166.	.7	.1	18	1	3	77
	300	22.2	1.4	.1	N.R.	N.R.	nil	N.R.
	N.R.	N.R.	neg.	nil	N.R.	N.R.	N.R.	N.R.
	N.R.	N.R.	nil	nil	N.R.	N.R.	N.R.	N.R.
	800	166.	.7	.1	18	1	3	77
	N.R.	N.R.	N.R.	nil	N.R.	N.R.	N.R.	N.R.
	900	20.	.02	nil	4	6	N.R.	N.R.
	1300	38.	nil	nil	10	8	N.R.	N.R.
	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
gas	180	8.	.4	nil	N.R.	N.R.	nil	N.R.

rning of sulfur for sulfuric acid production
rted in this table.

acid plant tail gas

t reported

significant quantity

nor quantity present, but not
ported or estimated

B

GAS FLOWS AND COMPOSITIONS - LEAD SMELTE

Plant Code No.	Gas Source or Point of Measurement	Temperature ^{o}F	Volume, thousand scfm	C o m p	
				SO_2	SO_3
326.09	Sintering - first stage (to acid plant)	300	8.2	4.7	0.3
	Sintering - second stage	N.R.	N.R.	N.R.	nil
	Blast furnace	400	8.5	.27	nil
	Refinery	N.R.	N.R.	nil	nil
	Dross reverb	1700	1.1	.99	nil
	Acid plant tail gas	180	4.5	.07	nil
	600-ft stack	N.R.	N.R.	N.R.	nil
326.10	Sinter machine	400	32.4	4.8	.3
	Blast furnace	450	11.1	.08	nil
	Refinery	N.R.	N.R.	nil	nil
	Dross reverb	1400	8.5	.02	nil
	Cadmium roaster	N.R.	N.R.	neg.	nil
	Slag fuming	600	59.3	.03	nil
	200-ft stack	180	262.	.62	nil
	200-ft stack	N.R.	N.R.	neg.	nil
326.17	Sinter machine	300	34.	4.8	.3
	Blast furnace	350	26.2	.07	nil
	Refinery	N.R.	N.R.	nil	nil
	Dross reverb	N.R.	N.R.	neg.	nil
	Acid plant tail gas	110	28.2	.08	nil
	Stack	N.R.	220.	.03	nil
326.18	Sinter machine	350	35.5	3.3	.2
	Blast furnace	300	23.3	.04	nil
	Refinery	N.R.	N.R.	nil	nil
	Dross reverb	N.R.	N.R.	neg.	nil
	400-ft stack	160	105.7	1.1	.05
	Stack	150	126.	.007	nil
326.19	Slag fuming	2200	9.0	.85	nil
	Stack	200	216.	.04	nil

(concluded on next sheet)

A

Appendix A
Table A - 6
Sheet 1 of 2

GAS FLOWS AND COMPOSITIONS - LEAD SMELTERS

Temperature °F	Volume, thousand scfm	Composition, volume percent SO_2	SO_3	O_2	CO_2	H_2O	N_2	CO
300	8.2	4.7	0.3	14	3	10	68	
N.R.	N.R.	N.R.	nil	19	N.R.	nil	78	
400	8.5	.27	nil	6	16	nil	73	5
N.R.	N.R.	nil	nil	N.R.	N.R.	N.R.	N.R.	
1700	1.1	.99	nil	N.R.	N.R.	neg.	N.R.	
180	4.5	.07	nil	15	3	nil	82	
N.R.	N.R.	N.R.	nil	N.R.	N.R.	neg.	N.R.	
400	32.4	4.8	.3	11	1	16	67	
450	11.1	.08	nil	3	14	1	70	12
N.R.	N.R.	nil	nil	N.R.	N.R.	N.R.	N.R.	
1400	8.5	.02	nil	N.R.	N.R.	neg.	N.R.	
N.R.	N.R.	neg.	nil	N.R.	N.R.	neg.	N.R.	
600	59.3	.03	nil	N.R.	N.R.	neg.	N.R.	
180	262.	.62	nil	N.R.	N.R.	N.R.	N.R.	
N.R.	N.R.	neg.	nil	N.R.	N.R.	N.R.	N.R.	
300	34.	4.8	.3	10	3	22	60	
350	26.2	.07	nil	5	15	nil	75	5
N.R.	N.R.	nil	nil	N.R.	N.R.	N.R.	N.R.	
N.R.	N.R.	neg.	nil	N.R.	N.R.	neg.	N.R.	
110	28.2	.08	nil	N.R.	N.R.	nil	N.R.	
N.R.	220.	.03	nil	N.R.	N.R.	N.R.	N.R.	
350	35.5	3.3	.2	N.R.	N.R.	N.R.	N.R.	
300	23.3	.04	nil	N.R.	neg.	nil	N.R.	N.R.
N.R.	N.R.	nil	nil	N.R.	N.R.	N.R.	N.R.	
N.R.	N.R.	neg.	nil	N.R.	N.R.	neg.	N.R.	
160	105.7	1.1	.05	N.R.	N.R.	N.R.	N.R.	
150	126.	.007	nil	N.R.	N.R.	N.R.	N.R.	
2200	9.0	.85	nil	N.R.	N.R.	neg.	N.R.	
200	216.	.04	nil	N.R.	N.R.	neg.	N.R.	

B

Plant Code No.	Gas Source or Point of Measurement	Temperature °F	Volume, thousand scfm	SO_2
326.33	Sinter machine	300	N.R.	N.R.
	Blast furnace	350	20.4	0.002
	Refinery	N.R.	N.R.	nil
	Dross reverb	1700	N.R.	neg.
	Cadmium roaster	N.R.	N.R.	neg.
	Slag fuming	600	19.7	.24
	Deleading kiln	2500	4.0	neg.
	600-ft stack	180	188.	.78
	300-ft stack	N.R.	N.R.	neg.
326.34	Sinter machine	350	N.R.	N.R.
	Blast furnace	300	N.R.	neg.
	Refinery	N.R.	N.R.	nil
	Dross reverb	1650	6.0	.52
	Cadmium roaster	N.R.	N.R.	neg.
	Slag fuming	2200	50.0	.11
	Deleading kiln	1500	N.R.	neg.
	150-ft stack	110	121.	.67
	200-ft stack	300	95.0	.09
	Stack	N.R.	N.R.	neg.
	Stack	N.R.	N.R.	neg.

Notes:

N.R.	-	Not reported
nil	-	Insignificant quantity
neg.	-	Minor quantity present, but not reported or estimated

A

Appendix A
Table A - 6
Sheet 2 of 2

Temperature °F	Volume, thousand scfm	Composition, volume percent						
		SO_2	SO_3	O_2	CO_2	H_2O	N_2	CO
300	N.R.	N.R.	neg.	N.R.	N.R.	N.R.	N.R.	
350	20.4	0.002	nil	5	15	nil	75	5
N.R.	N.R.	nil	nil	N.R.	N.R.	N.R.	N.R.	
1700	N.R.	neg.	nil	N.R.	N.R.	neg.	N.R.	
N.R.	N.R.	neg.	nil	N.R.	N.R.	neg.	N.R.	
600	19.7	.24	nil	N.R.	N.R.	neg.	N.R.	
2500	4.0	neg.	nil	N.R.	N.R.	N.R.	N.R.	
180	188.	.78	nil	N.R.	N.R.	N.R.	N.R.	
N.R.	N.R.	neg.	nil	N.R.	N.R.	N.R.	N.R.	
350	N.R.	N.R.	neg.	N.R.	N.R.	N.R.	N.R.	
300	N.R.	neg.	nil	neg.	N.R.	nil	N.R.	N.R.
N.R.	N.R.	nil	nil	N.R.	N.R.	N.R.	N.R.	
1650	6.0	.52	nil	N.R.	N.R.	neg.	N.R.	
N.R.	N.R.	neg.	nil	N.R.	N.R.	neg.	N.R.	
2200	50.0	.11	nil	N.R.	N.R.	neg.	N.R.	
1500	N.R.	neg.	nil	N.R.	N.R.	N.R.	N.R.	
110	121.	.67	nil	N.R.	N.R.	N.R.	N.R.	
300	95.0	.09	nil	18	1	neg.	79	2
N.R.	N.R.	neg.	nil	N.R.	N.R.	N.R.	N.R.	
N.R.	N.R.	neg.	nil	N.R.	N.R.	N.R.	N.R.	

d

nt quantity

ity present, but not
estimated

B

ANALYSIS OF SULFUR OXIDES GENERAT

Industry	Smelter Equipment	**Sulfur Dioxide Concentration, volume percent	Number of Smelters in This Class	Sulfu Ge 1000 t
Copper	Roasters	3.0 & less	0	--
		3.1 to 6.0	1	139.4
		6.1 & up	4	169.9
		Not reported	2	50.8
	Reverbs	3.0 & less	14	349.5
		3.1 to 6.0	1	27.0
		6.1 & up	0	--
		Not reported	2	14.6
	Converters		4	318.5
			12	746.2
		Total copper		
Zinc	Roasters	3.0 & less	2	53.5
		3.1 to 6.0	0	--
		6.1 & up	8	550.8
		Not reported	3	93.0
	Sinter-roasters	3.0 & less	1	60.1
	Sinter machines	3.0 & less	4	18.2
		Not reported	2	4.5
	Cokers, retorts, furnaces, kilns	3.0 & less	2	1.2
		Not reported	8	1.4
		Total zinc		

(concluded on next sheet)

Appendix A
Table A-7
Sheet 1 of 2

ANALYSIS OF SULFUR OXIDES GENERATION AND RECOVERY*

r Dioxide ntration, e percent	Number of Smelters in This Class	Sulfur Equivalent Generated 1000 tons per year		Sulfur Equivalent Recovered 1000 tons per year		Recovery, percent	Number of Smelters Recovering
& less	0	--		--		--	
to 6.0	1	139.4		0		0	
& up	4	169.9		127.1		74.8	3
reported	2	50.8		0		0	
			360.1		127.1	35.3	
& less	14	349.5		0		0	
to 6.0	1	27.0		0		0	
& up	0	--		--		--	
reported	2	14.6		0		0	
			391.1		0	0	
	4	318.5		217.1		68.2	4
	12	746.2		0		0	
			1,064.7		217.1	20.4	
Total copper			1,815.9		344.2	19.0	
& less	2	53.5		0		0	
to 6.0	0	--		--		--	
& up	8	550.8		435.3		79.0	8
reported	3	93.0		26.3		28.3	1
			697.3		461.6	66.2	
less	1	60.1		0		0	
			60.1		0	0	
less	4	18.2		0		0	
eported	2	4.5		0		0	
			22.7		0	0	
less	2	1.2		0		0	
eported	8	1.4		0		0	
			2.6		0	0	
Total zinc			782.7		461.6	59.0	

B

Industry	Smelter Equipment	**Sulfur Dioxide Concentration, volume percent	Number of Smelters in This Class	Sul 100
Lead	Sinter machines	3.0 & less	0	
		3.1 to 6.0	4	12
		6.1 & up	0	
		Not reported	2	4
	Blast furnaces	3.0 & less	6	3
	Other	3.0 & less	7	5
		Total lead		

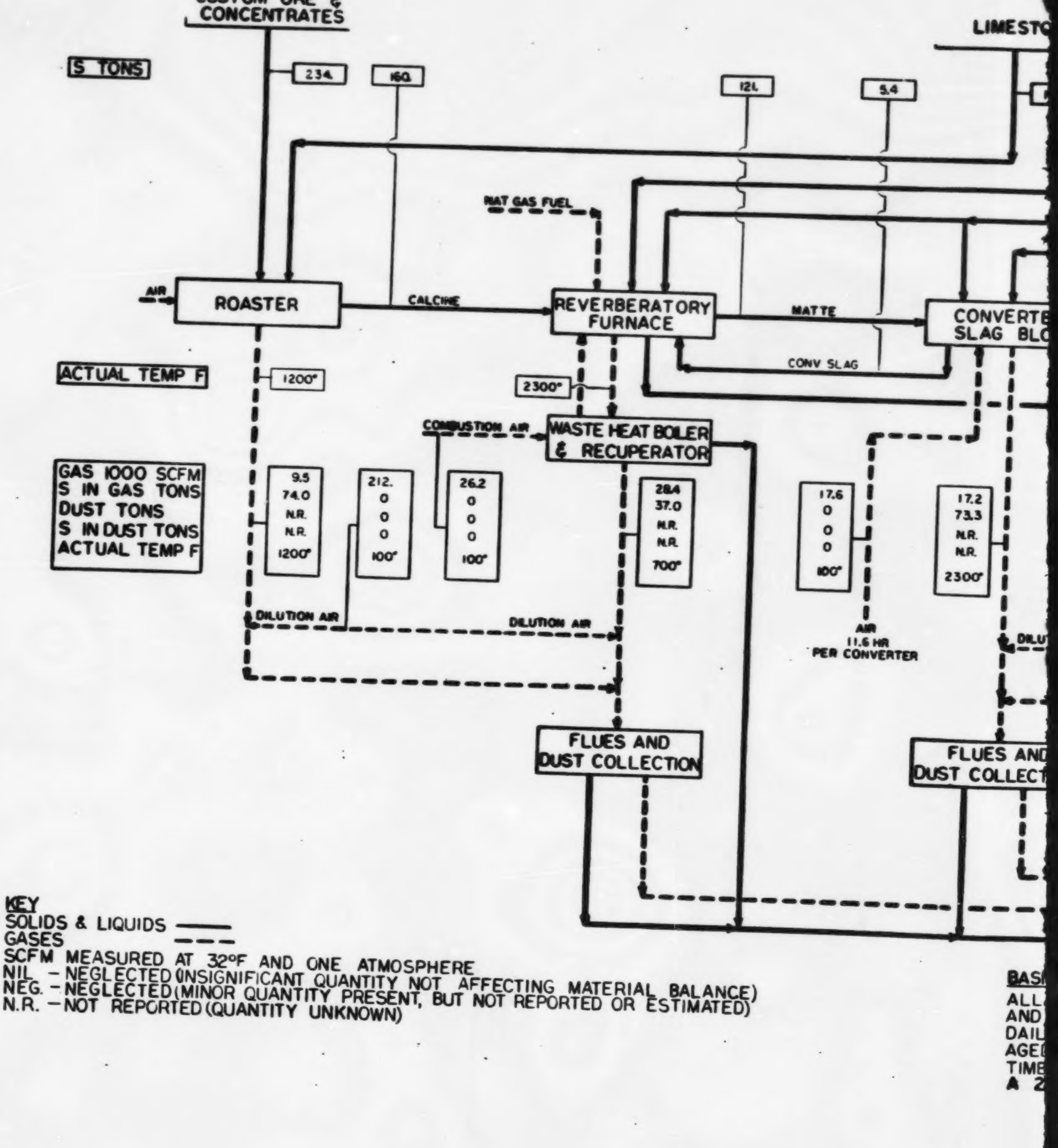
* All data taken from Appendix A tables and flow diagrams

** Concentration before air dilution

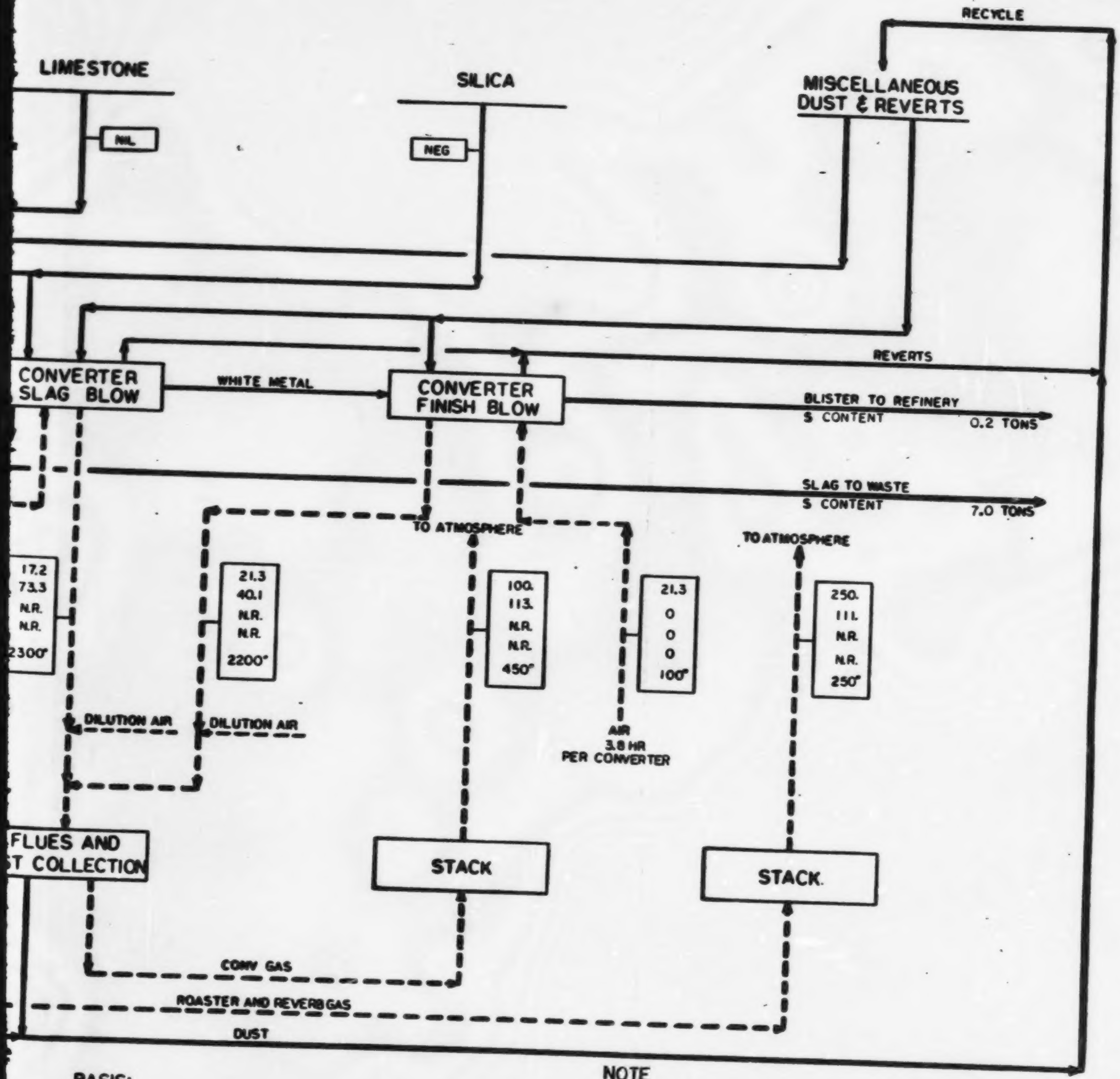
Appendix A
Table A-7
Sheet 2 of 2

ioxide ation, ercent	Number of Smelters in This Class	Sulfur Equivalent Generated 1000 tons per year		Sulfur Equivalent Recovered 1000 tons per year		Recovery, percent	Number of Smelters Recovering
less	0	--		--		--	
6.0	4	123.0		47.1		38.3	2
up	0	--		--		--	
ported	2	47.3		0		0	
			170.3		47.1	27.7	
less	6	3.0		0		0	
			3.0		0	0	
less	7	5.4		0		0	
			5.4		0	0	
Total lead			178.7		47.1	26.4	

B


CUSTOM ORE & CONCENTRATES
LIMESTO
S TONS
234.
160.
121.
5.4
NAT GAS FUEL
AIR
ROASTER
CALCINE
REVERBERATORY FURNACE
MATTE
CONVERTE SLAG BL
CONV SLAG
ACTUAL TEMP F
1200°
2300°
COMBUSTION AIR
WASTE HEAT BOILER & RECUPERATOR
GAS 1000 SCFM
S IN GAS TONS
DUST TONS
S IN DUST TONS
ACTUAL TEMP F
9.5 74.0 N.R. N.R. 1200°
212. 0 0 0 100°
26.2 0 0 0 100°
28.4 37.0 N.R. N.R. 700°
17.6 0 0 0 100°
17.2 73.3 N.R. N.R. 2300°
DILUTION AIR
DILUTION AIR
AIR 11.6 HR PER CONVERTER
DILU
FLUES AND DUST COLLECTION
FLUES AND DUST COLLECT
BASI
ALL
AND
DAIL
AGE
TIME
A 2

KEY
SOLIDS & LIQUIDS ———
GASES – – –
SCFM MEASURED AT 32°F AND ONE ATMOSPHERE
NIL – NEGLECTED (INSIGNIFICANT QUANTITY NOT AFFECTING MATERIAL BALANCE)
NEG. – NEGLECTED (MINOR QUANTITY PRESENT, BUT NOT REPORTED OR ESTIMATED)
N.R. – NOT REPORTED (QUANTITY UNKNOWN)


RECYCLE
LIMESTONE
NIL
SILICA
NEG
MISCELLANEOUS DUST & REVERTS
REVERTS
CONVERTER SLAG BLOW
WHITE METAL
CONVERTER FINISH BLOW
BLISTER TO REFINERY
S CONTENT 0.2 TONS
SLAG TO WASTE
S CONTENT 7.0 TONS
TO ATMOSPHERE
TO ATMOSPHERE
17.2 73.3 N.R. N.R. 2300°
21.3 40.1 N.R. N.R. 2200°
100. 113. N.R. N.R. 450°
21.3 0 0 0 100°
250. 111. N.R. N.R. 250°
DILUTION AIR
DILUTION AIR
AIR 3.8 HR PER CONVERTER
FLUES AND
T COLLECTION
STACK
STACK
CONV GAS
ROASTER AND REVERB GAS
DUST

BASIS:

ALL FLOW QUANTITIES ARE ESTIMATED. ROASTER AND REVERBERATORY GASES ARE SHOWN ON A DAILY RATE BASIS. CONVERTER GASES ARE AVERAGED FOR A BLOW TIME OF 11.7HR TOTAL ELAPSED TIME. TONNAGES ARE GIVEN IN SHORT TONS FOR A 24 HOUR PERIOD

NOTE

ALTHOUGH SHOWN AS SEPARATE BLOCKS THE SAME CONVERTER IS USED FOR SLAG AND FINISH BLOWS

B

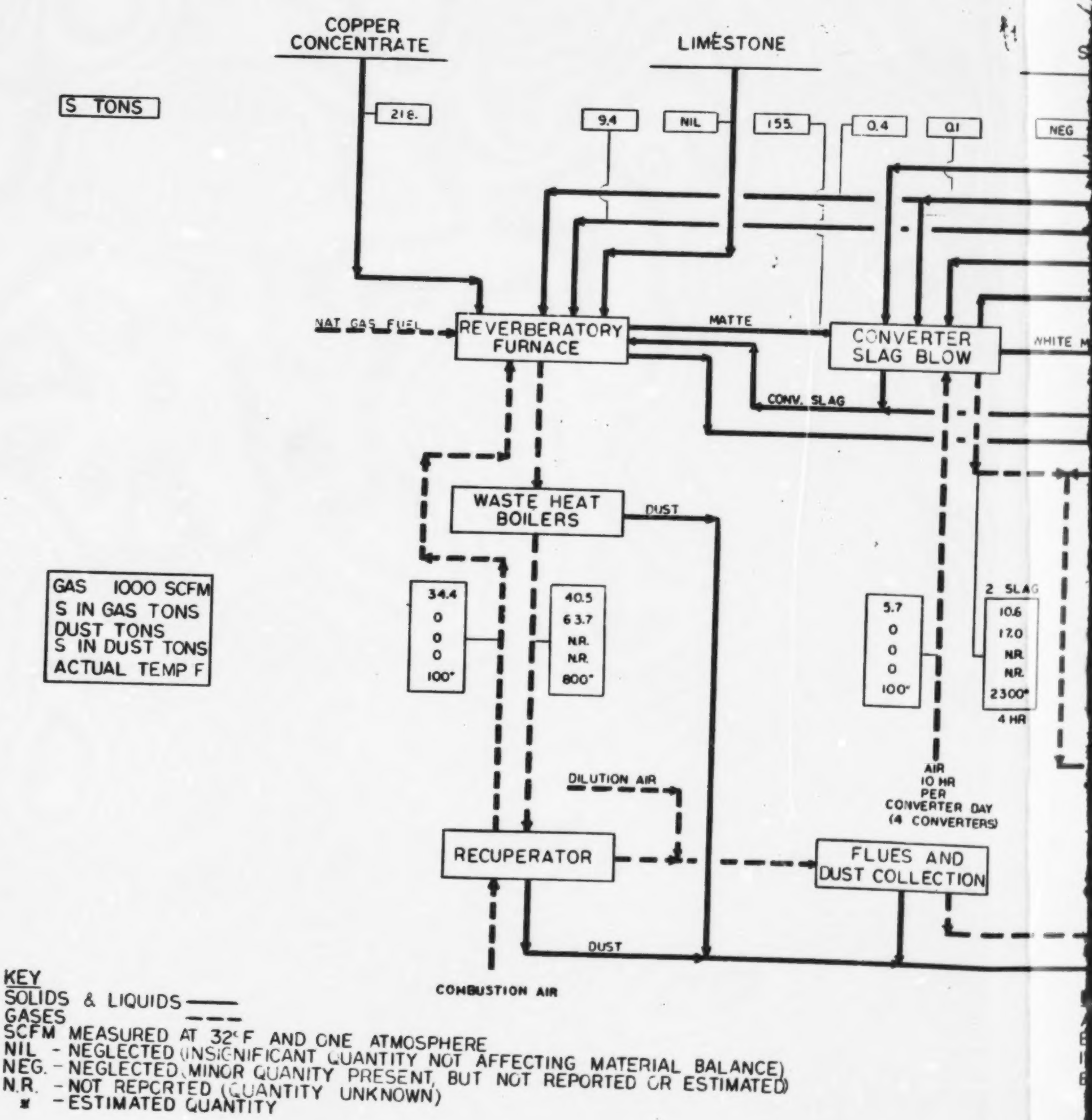
NATIONAL AIR
POLLUTION CONTROL
ADMINISTRATION

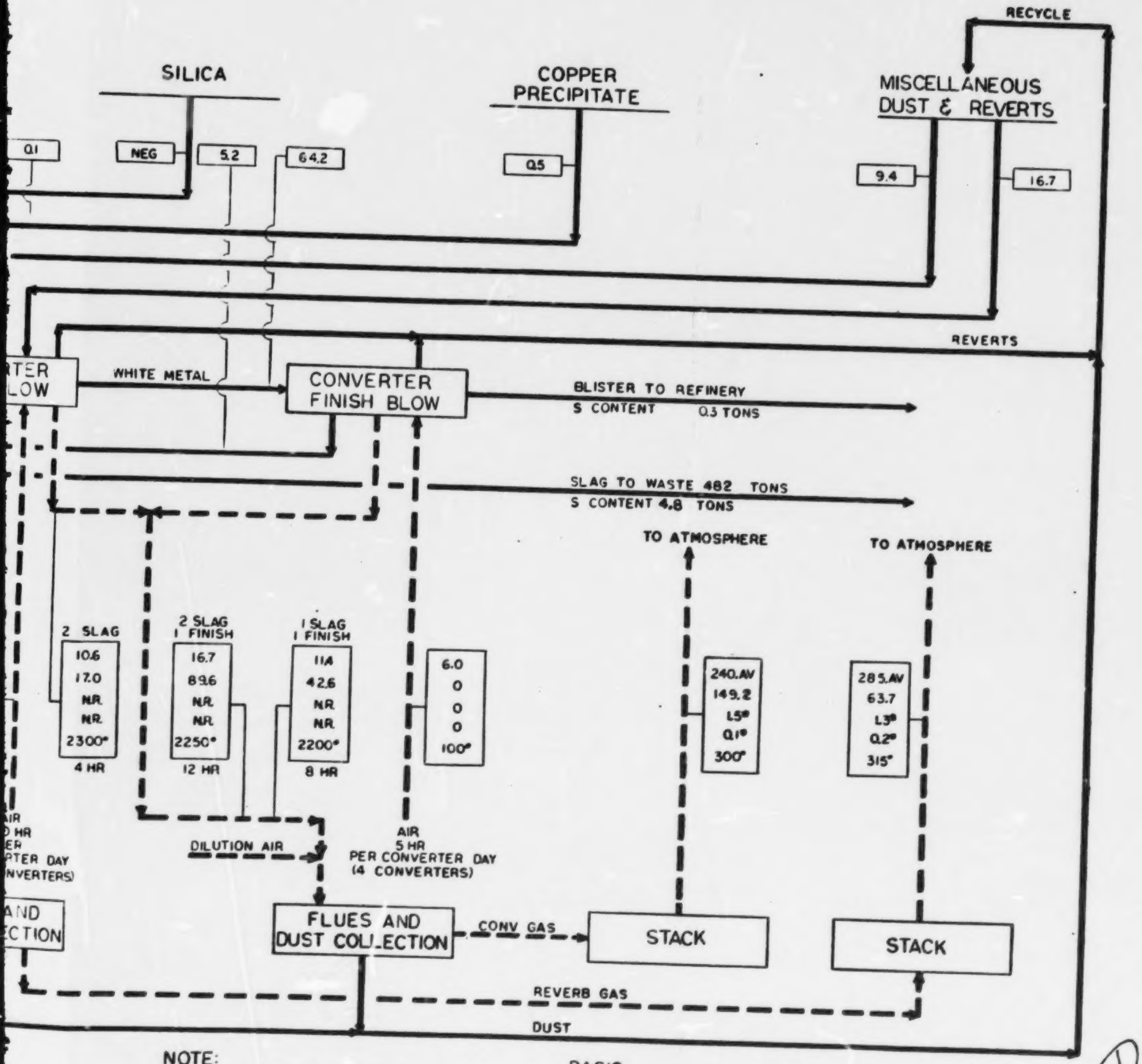
326.01
COPPER PLANT
FLOW DIAGRAM

ARTHUR G. McKEE & COMPANY
WESTERN KNAPP ENGINEERING DIVISION
SAN FRANCISCO CALIFORNIA

ENG. DEPT. DWG. 10-01-002

PLATE NO. A-1

COPPER CONCENTRATE
LIMESTONE
S TONS
218.
9.4
NIL
155.
0.4
0.1
NEG
NAT GAS FUEL
REVERBERATORY FURNACE
MATTE
CONVERTER SLAG BLOW
WHITE M
CONV. SLAG
WASTE HEAT BOILERS
DUST
GAS 1000 SCFM
S IN GAS TONS
DUST TONS
S IN DUST TONS
ACTUAL TEMP F
34.4
0
0
0
100°
40.5
63.7
N.R.
N.R.
800°
5.7
0
0
0
100°
2 SLAG
10.6
17.0
NR.
NR.
2300°
4 HR
AIR
10 HR PER CONVERTER DAY
(4 CONVERTERS)
DILUTION AIR
RECUPERATOR
FLUES AND DUST COLLECTION
DUST
COMBUSTION AIR
KEY
SOLIDS & LIQUIDS
GASES
SCFM MEASURED AT 32°F AND ONE ATMOSPHERE
NIL - NEGLECTED (INSIGNIFICANT QUANTITY NOT AFFECTING MATERIAL BALANCE)
NEG. - NEGLECTED (MINOR QUANITY PRESENT, BUT NOT REPORTED OR ESTIMATED)
N.R. - NOT REPORTED (QUANTITY UNKNOWN)
* - ESTIMATED QUANTITY


RECYCLE
SILICA
COPPER PRECIPITATE
MISCELLANEOUS DUST & REVERTS
0.1
NEG
5.2
64.2
0.5
9.4
16.7
REVERTS
TER
LOW
WHITE METAL
CONVERTER FINISH BLOW
BLISTER TO REFINERY
S CONTENT 0.3 TONS
SLAG TO WASTE 482 TONS
S CONTENT 4.8 TONS
TO ATMOSPHERE
TO ATMOSPHERE
2 SLAG
10.6
17.0
N.R.
N.R.
2300°
4 HR
2 SLAG 1 FINISH
16.7
89.6
N.R.
N.R.
2250°
12 HR
1 SLAG 1 FINISH
11.4
42.6
N.R.
N.R.
2200°
8 HR
6.0
0
0
0
100°
240.AV
149.2
1.5°
0.1°
300°
285.AV
63.7
1.3°
0.2°
315°
AIR
D HR
ER
RTER DAY
NVERTERS)
DILUTION AIR
AIR
5 HR
PER CONVERTER DAY
(4 CONVERTERS)
AND
ECTION
FLUES AND DUST COLLECTION
CONV GAS
STACK
STACK
REVERB GAS
DUST

NOTE:
ALTHOUGH SHOWN AS SEPARATE BLOCKS THE SAME CONVERTER IS USED FOR SLAG AND FINISH BLOWS

BASIS:
TONNAGES ARE GIVEN FOR A 24-HOUR PERIOD IN SHORT TONS

S-SULFUR

B

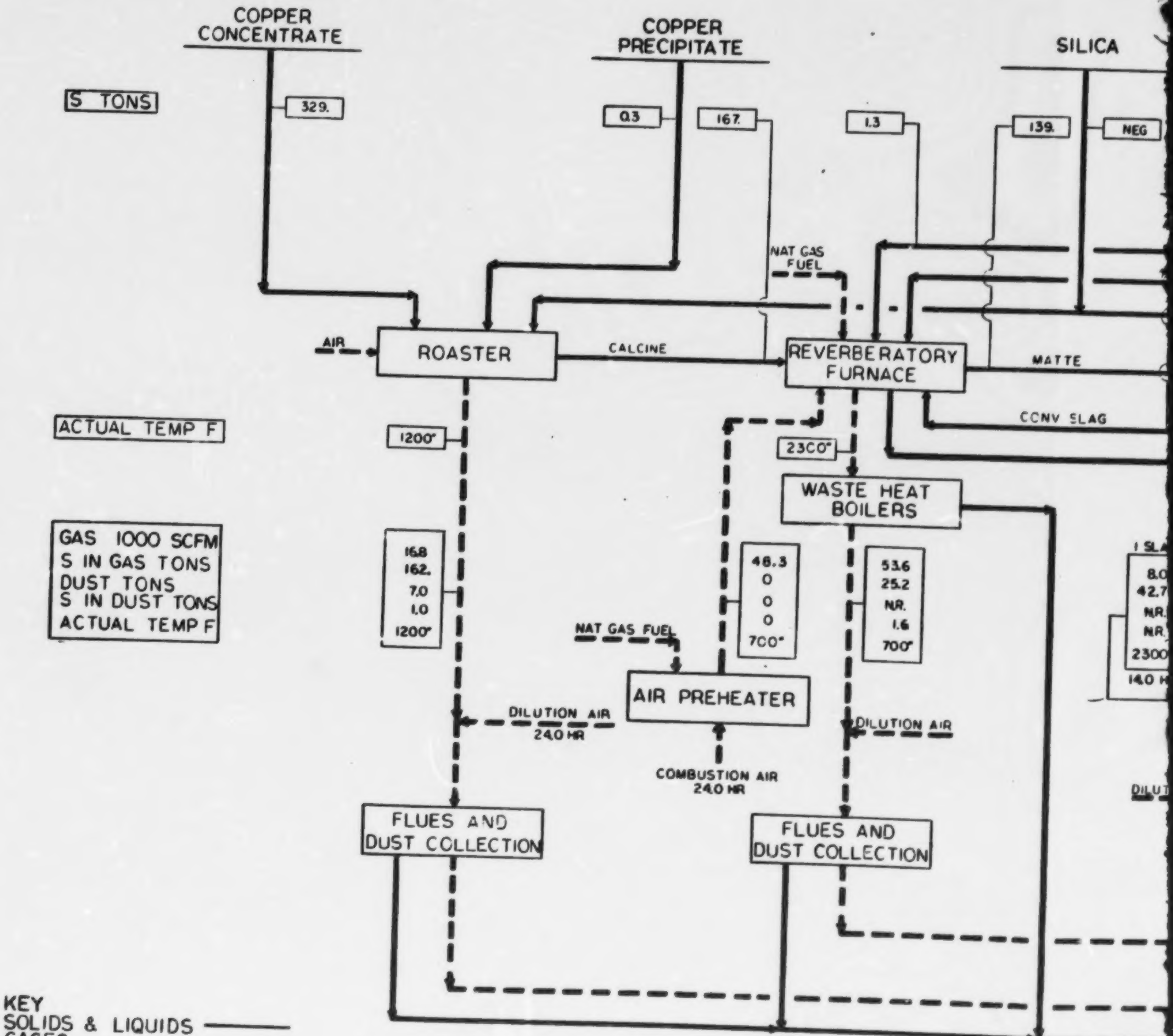
NATIONAL AIR
POLLUTION CONTROL
ADMINISTRATION

ARTHUR G. McKEE & COMPANY
WESTERN KNAPP ENGINEERING DIVISION
SAN FRANCISCO CALIFORNIA

TITLE
326.02
COPPER PLANT
FLOW DIAGRAM

ENG. DEPT. DWG. 10-01-003

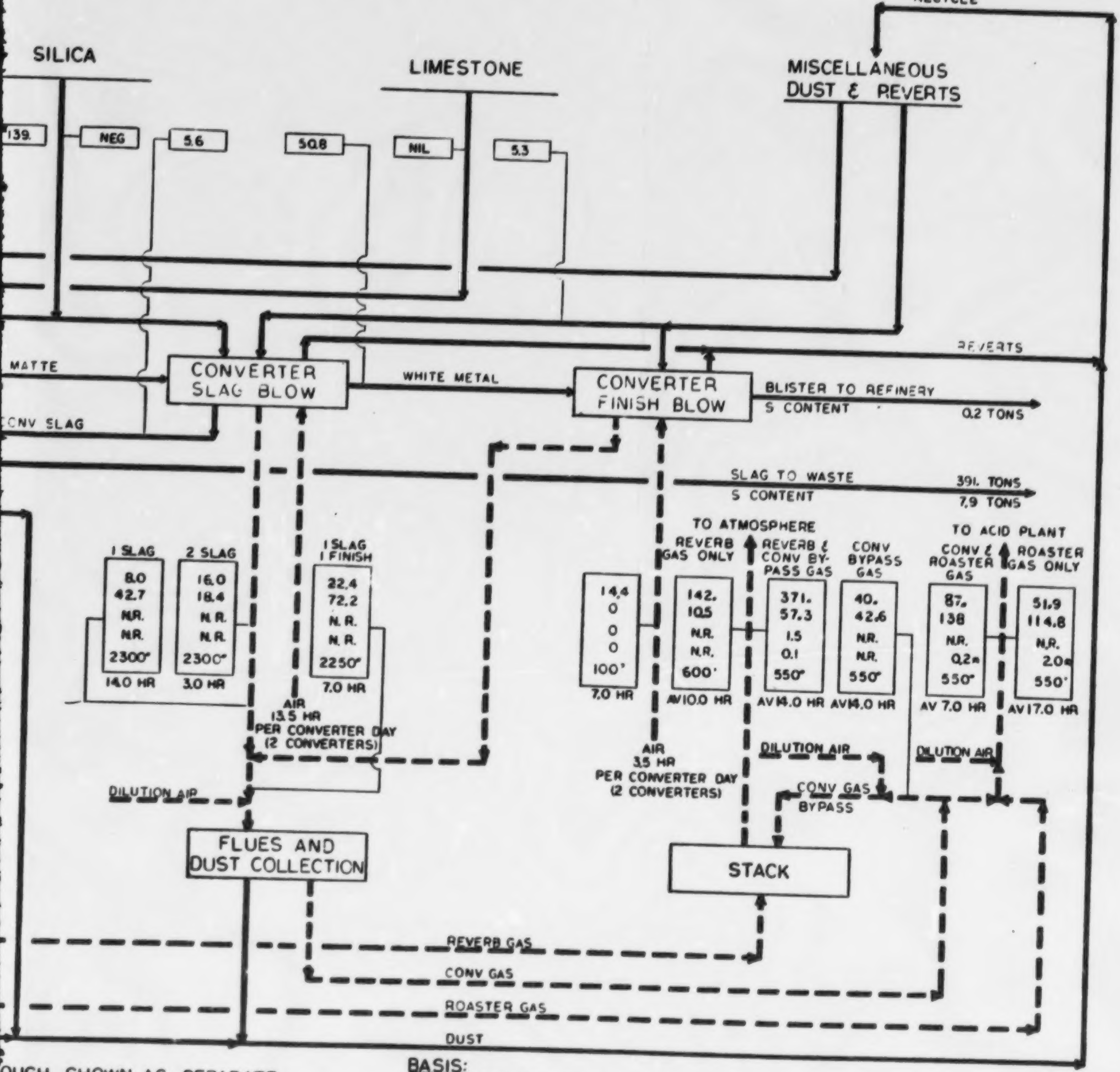
PLATE NO. A-2


COPPER CONCENTRATE
COPPER PRECIPITATE
SILICA
S TONS
329.
0.3
167.
1.3
139.
NEG
NAT GAS FUEL
AIR
ROASTER
CALCINE
REVERBERATORY FURNACE
MATTE
CONV SLAG
ACTUAL TEMP F
1200°
2300°
WASTE HEAT BOILERS
GAS 1000 SCFM
S IN GAS TONS
DUST TONS
S IN DUST TONS
ACTUAL TEMP F
16.8
162.
7.0
1.0
1200°
46.3
0
0
0
700°
53.6
25.2
N.R.
1.6
700°
NAT GAS FUEL
AIR PREHEATER
DILUTION AIR
24.0 HR
COMBUSTION AIR
24.0 HR
DILUTION AIR
FLUES AND DUST COLLECTION
FLUES AND DUST COLLECTION
8.0
42.7
N.R.
N.R.
2300
14.0 H
DILUT

KEY
SOLIDS & LIQUIDS ————
GASES — — —
SCFM MEASURED AT 32°F AND ONE ATMOSPHERE
NIL - NEGLECTED (INSIGNIFICANT QUANTITY NOT AFFECTING MATERIAL BALANCE)
NEG. - NEGLECTED (MINOR QUANTITY PRESENT, BUT NOT REPORTED OR ESTIMATED)
N.R. - NOT REPORTED (QUANTITY UNKNOWN)
* - ESTIMATED QUANTITY

NOTE:
ALTHOUGH SHOWN
BLOCKS THE SAME
IS USED FOR SLAG
BLOWS

A


RECYCLE
SILICA
LIMESTONE
MISCELLANEOUS
DUST & REVERTS
139.
NEG
5.6
50.8
NIL
5.3
MATTE
CONV SLAG
CONVERTER
SLAG BLOW
WHITE METAL
CONVERTER
FINISH BLOW
REVERTS
BLISTER TO REFINERY
S CONTENT
0.2 TONS
SLAG TO WASTE
S CONTENT
391. TONS
7.9 TONS
1 SLAG
8.0
42.7
N.R.
N.R.
2300°
14.0 HR
2 SLAG
16.0
18.4
N.R.
N.R.
2300°
3.0 HR
1 SLAG
1 FINISH
22.4
72.2
N.R.
N.R.
2250°
7.0 HR
AIR
13.5 HR
PER CONVERTER DAY
(2 CONVERTERS)
DILUTION AIR
FLUES AND
DUST COLLECTION
TO ATMOSPHERE
14.4
0
0
0
100°
7.0 HR
REVERB
GAS ONLY
142.
10.5
N.R.
N.R.
600°
AV10.0 HR
REVERB &
CONV BY-
PASS GAS
371.
57.3
1.5
0.1
550°
AV14.0 HR
CONV
BYPASS
GAS
40.
42.6
N.R.
N.R.
550°
AV14.0 HR
TO ACID PLANT
CONV &
ROASTER
GAS
87.
138
N.R.
0.2
550°
AV 7.0 HR
ROASTER
GAS ONLY
51.9
114.8
N.R.
2.0
550°
AV17.0 HR
AIR
3.5 HR
PER CONVERTER DAY
(2 CONVERTERS)
DILUTION AIR
DILUTION AIR
CONV GAS
BYPASS
STACK
REVERB GAS
CONV GAS
ROASTER GAS
DUST

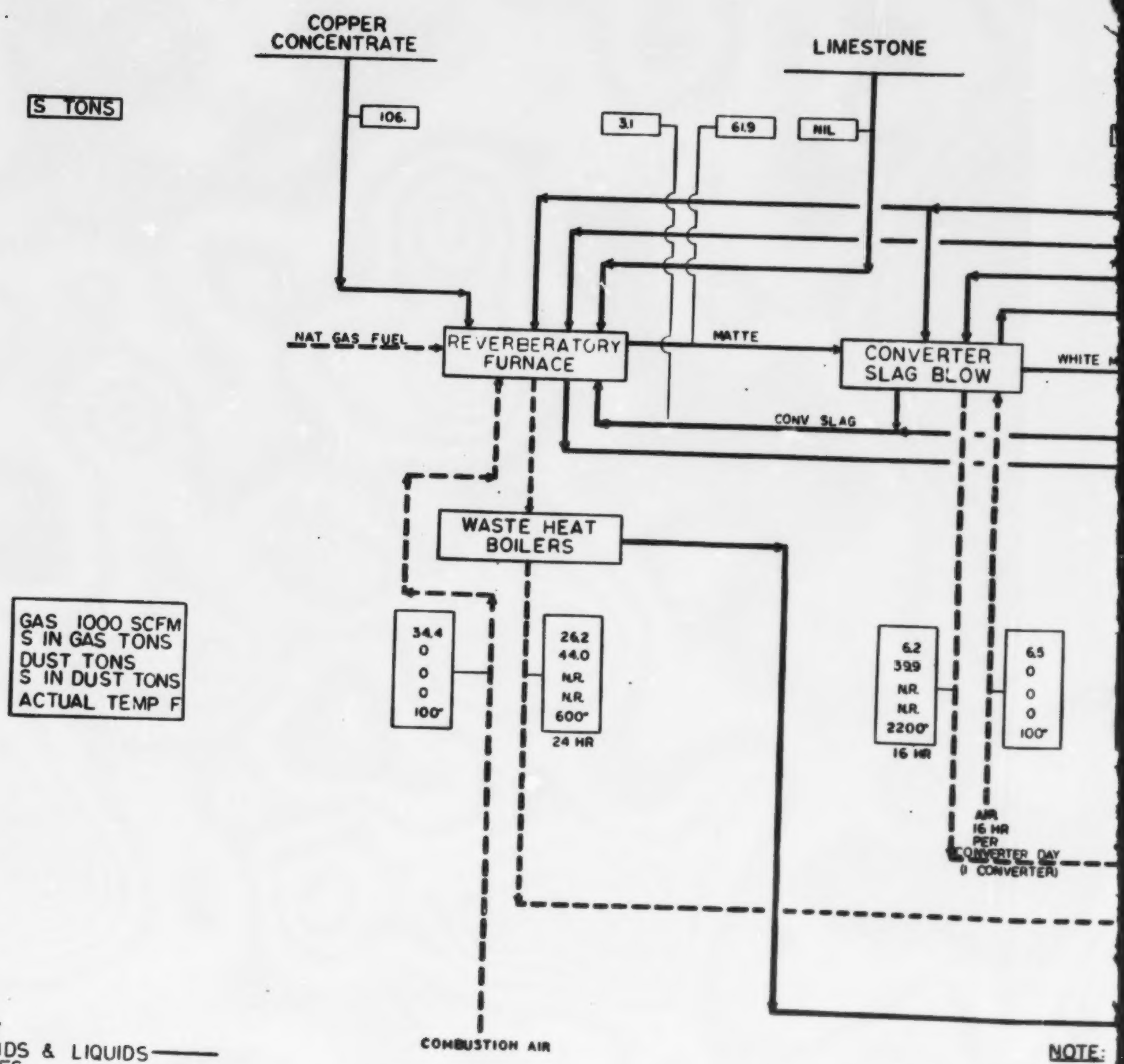
OUGH SHOWN AS SEPARATE
KS THE SAME CONVERTER
ED FOR SLAG AND FINISH
S

BASIS:
TONNAGES ARE GIVEN
FOR A 24-HOUR PERIOD
IN SHORT TONS

S-SULFUR

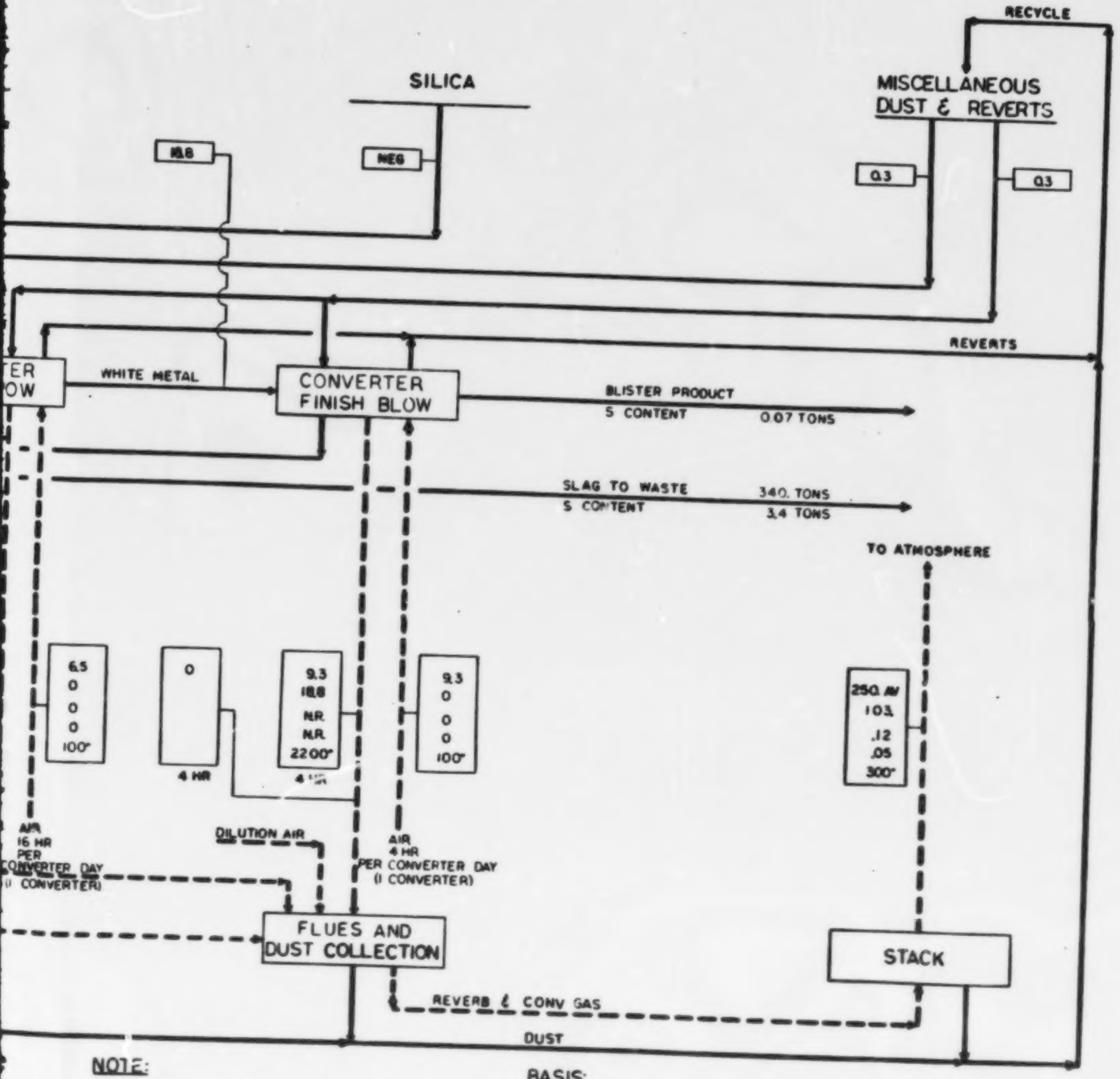
B

CLIENT NATIONAL AIR POLLUTION CONTROL ADMINISTRATION	ARTHUR G. McKEE & COMPANY WESTERN KNAPP ENGINEERING DIVISION SAN FRANCISCO CALIFORNIA
TITLE 326.03 COPPER PLANT FLOW DIAGRAM	ENG. DEPT. DWG. 10-01-004 PLATE NO. A-3


COPPER CONCENTRATE
LIMESTONE
S TONS
106.
3.1
61.9
NIL
NAT GAS FUEL
REVERBERATORY FURNACE
MATTE
CONVERTER SLAG BLOW
WHITE M
CONV SLAG
WASTE HEAT BOILERS
GAS 1000 SCFM
S IN GAS TONS
DUST TONS
S IN DUST TONS
ACTUAL TEMP F
34.4
0
0
0
100°
26.2
44.0
N.R.
N.R.
600°
24 HR
6.2
39.9
N.R.
N.R.
2200°
16 HR
6.5
0
0
0
100°
AIR
16 HR
PER
CONVERTER DAY
(1 CONVERTER)
COMBUSTION AIR

KEY
SOLIDS & LIQUIDS ———
GASES – – –
SCFM MEASURED AT 32°F AND ONE ATMOSPHERE
NIL - NEGLECTED (INSIGNIFICANT QUANTITY NOT AFFECTING MATERIAL BALANCE)
NEG. - NEGLECTED (MINOR QUANTITY PRESENT, BUT NOT REPORTED OR ESTIMATED)
N.R. - NOT REPORTED (QUANTITY UNKNOWN)

NOTE:
ALTHO
BLOCKS
IS USE
BLOWS


RECYCLE
SILICA
MISCELLANEOUS DUST & REVERTS
18.8
NEG
0.3
0.3
REVERTS
TER
OW
WHITE METAL
CONVERTER FINISH BLOW
BLISTER PRODUCT
S CONTENT
0.07 TONS
SLAG TO WASTE
340. TONS
S CONTENT
3.4 TONS
TO ATMOSPHERE
6.5
0
0
0
100°
0
4 HR
9.3
18.8
N.R.
N.R.
2200°
4 HR
9.3
0
0
0
100°
250. AV
10.3
.12
.05
300°
AIR
16 HR
PER
CONVERTER DAY
(1 CONVERTER)
DILUTION AIR
AIR
4 HR
PER CONVERTER DAY
(1 CONVERTER)
FLUES AND DUST COLLECTION
STACK
REVERB & CONV GAS
DUST

NOTE:

ALTHOUGH SHOWN AS SEPARATE BLOCKS THE SAME CONVERTER IS USED FOR SLAG AND FINISH BLOWS

BASIS:

TONNAGES ARE GIVEN FOR A 24-HOUR PERIOD IN SHORT TONS

S-SULFUR

B

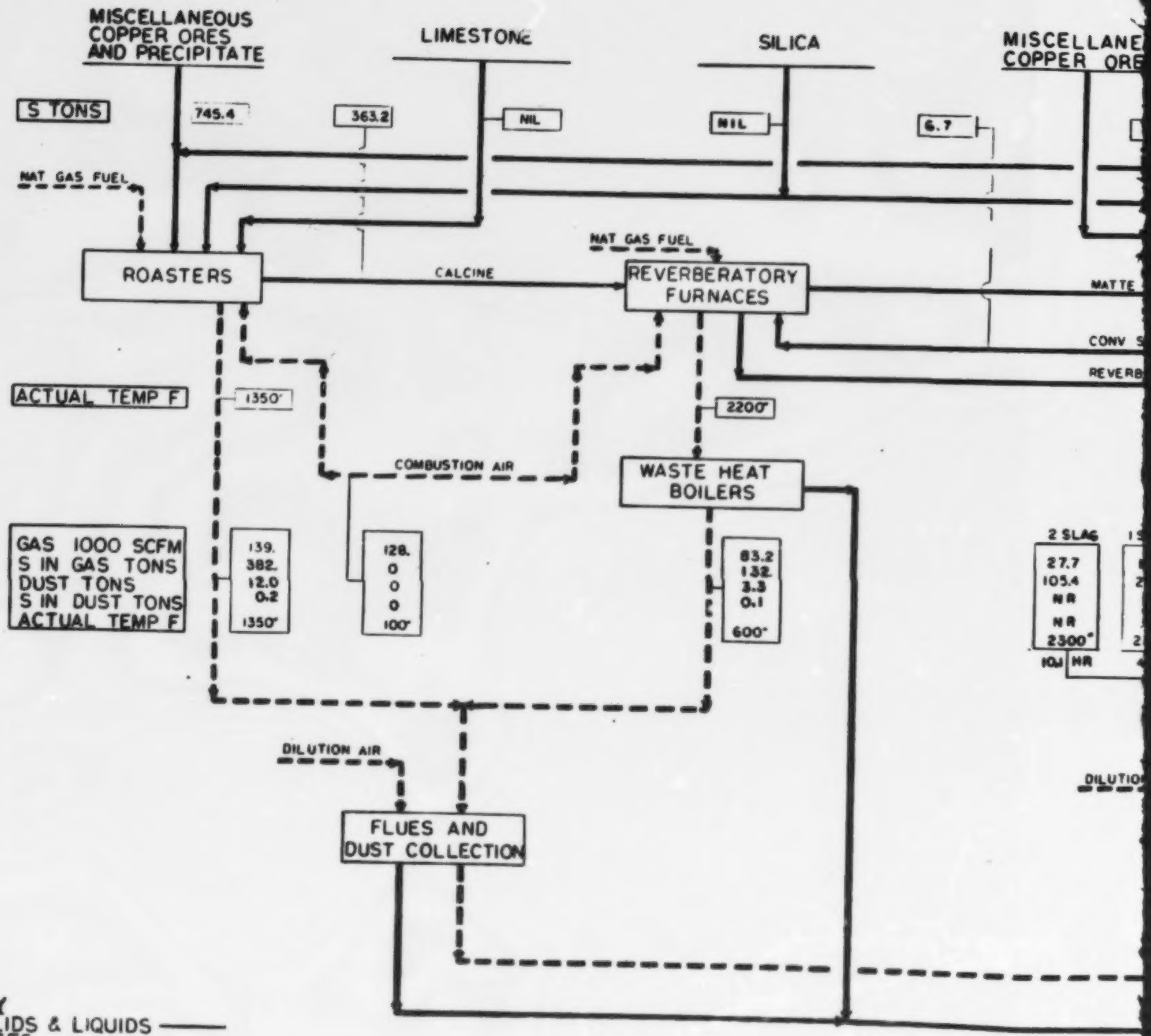
NATIONAL AIR
POLLUTION CONTROL
ADMINISTRATION

326.04
COPPER PLANT
FLOW DIAGRAM

ARTHUR G. McKEE & COMPANY
WESTERN KNAPP ENGINEERING DIVISION
SAN FRANCISCO CALIFORNIA

ENG. DEPT. DWG. 10-01-005

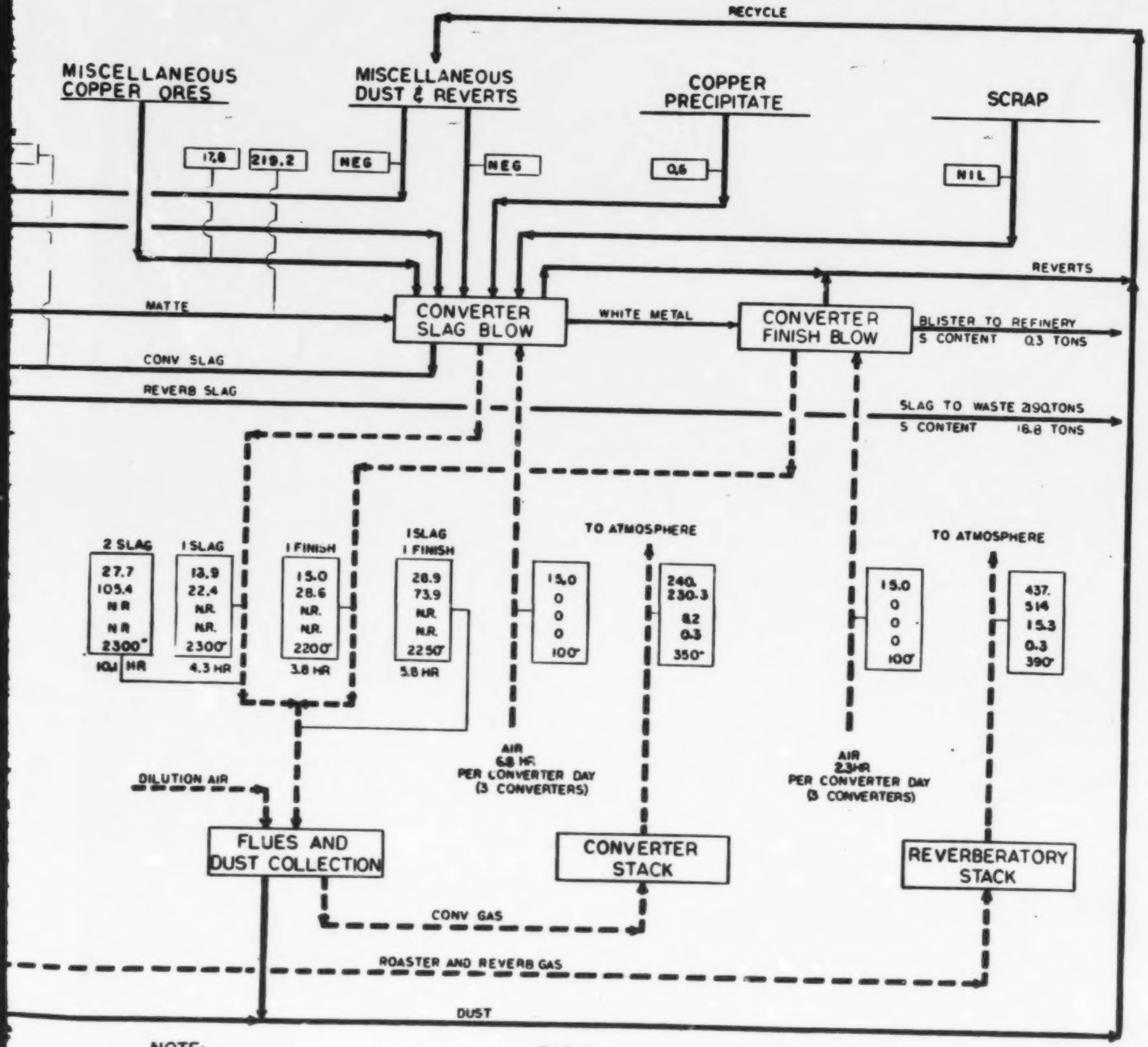
PLATE NO. A-4


MISCELLANEOUS COPPER ORES AND PRECIPITATE
LIMESTONE
SILICA
MISCELLANE
COPPER ORE
S TONS
745.4
363.2
NIL
NIL
6.7
NAT GAS FUEL
ROASTERS
CALCINE
NAT GAS FUEL
REVERBERATORY FURNACES
MATTE
CONV S
REVERB
ACTUAL TEMP F
1350°
2200°
COMBUSTION AIR
WASTE HEAT BOILERS
GAS 1000 SCFM
S IN GAS TONS
DUST TONS
S IN DUST TONS
ACTUAL TEMP F
139.
382.
12.0
0.2
1350°
128.
0
0
0
100°
83.2
132.
3.3
0.1
600°
2 SLAG
27.7
105.4
NR
NR
2300°
10.1 HR
DILUTION AIR
DILUTION
FLUES AND DUST COLLECTION

KEY
SOLIDS & LIQUIDS ———
GASES - - -
SCFM MEASURED AT 32°F AND ONE ATMOSPHERE
NIL - NEGLECTED (INSIGNIFICANT QUANTITY NOT AFFECTING MATERIAL BALANCE)
NEG. - NEGLECTED (MINOR QUANTITY PRESENT, BUT NOT REPORTED OR ESTIMATED)
N.R. - NOT REPORTED (QUANTITY UNKNOWN)

NOT
ALTH
BLO
IS U
BLOW

A


RECYCLE
MISCELLANEOUS COPPER ORES
MISCELLANEOUS DUST & REVERTS
COPPER PRECIPITATE
SCRAP
17.8
219.2
NEG
NEG
0.6
NIL
REVERTS
MATTE
CONVERTER SLAG BLOW
WHITE METAL
CONVERTER FINISH BLOW
BLISTER TO REFINERY
S CONTENT 0.3 TONS
CONV SLAG
REVERB SLAG
SLAG TO WASTE 2190 TONS
S CONTENT 18.8 TONS
2 SLAG
27.7
105.4
N R
N R
2300°
10.1 HR
1 SLAG
13.9
22.4
N.R.
N.R.
2300°
4.3 HR
1 FINISH
15.0
28.6
N.R.
N.R.
2200°
3.8 HR
1 SLAG
1 FINISH
28.9
73.9
N.R.
N.R.
2250°
5.8 HR
15.0
0
0
0
100°
TO ATMOSPHERE
240.
230.3
8.2
0.3
350°
15.0
0
0
0
100°
TO ATMOSPHERE
437.
514
15.3
0.3
390°
AIR
6.8 HR
PER CONVERTER DAY
(3 CONVERTERS)
AIR
2.3 HR
PER CONVERTER DAY
(3 CONVERTERS)
DILUTION AIR
FLUES AND DUST COLLECTION
CONVERTER STACK
REVERBERATORY STACK
CONV GAS
ROASTER AND REVERB GAS
DUST

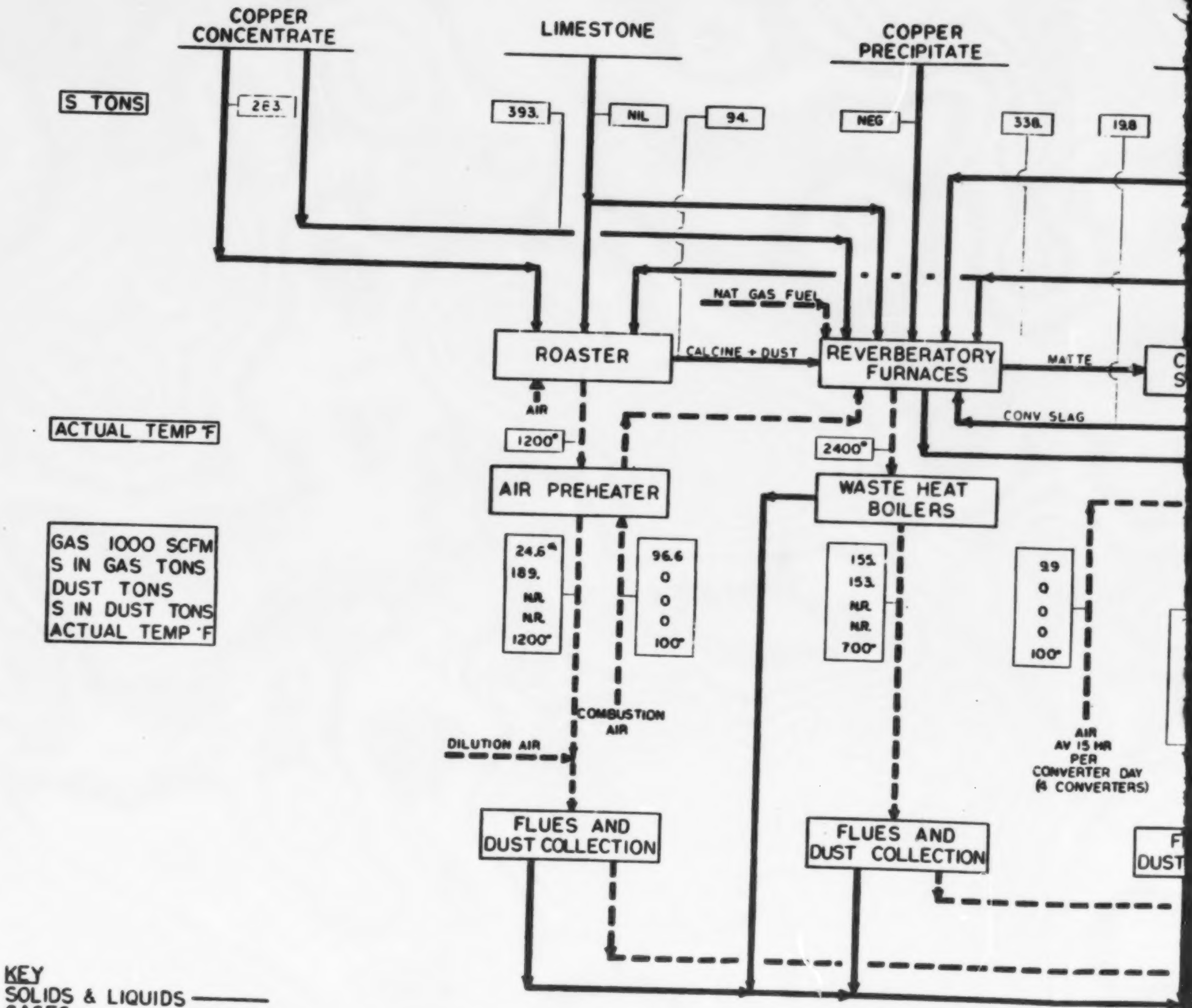
NOTE:
ALTHOUGH SHOWN AS SEPARATE BLOCKS THE SAME CONVERTER IS USED FOR SLAG AND FINISH BLOWS

BASIS:
TONNAGES ARE GIVEN FOR A 24-HOUR PERIOD IN SHORT TONS

S-SULFUR

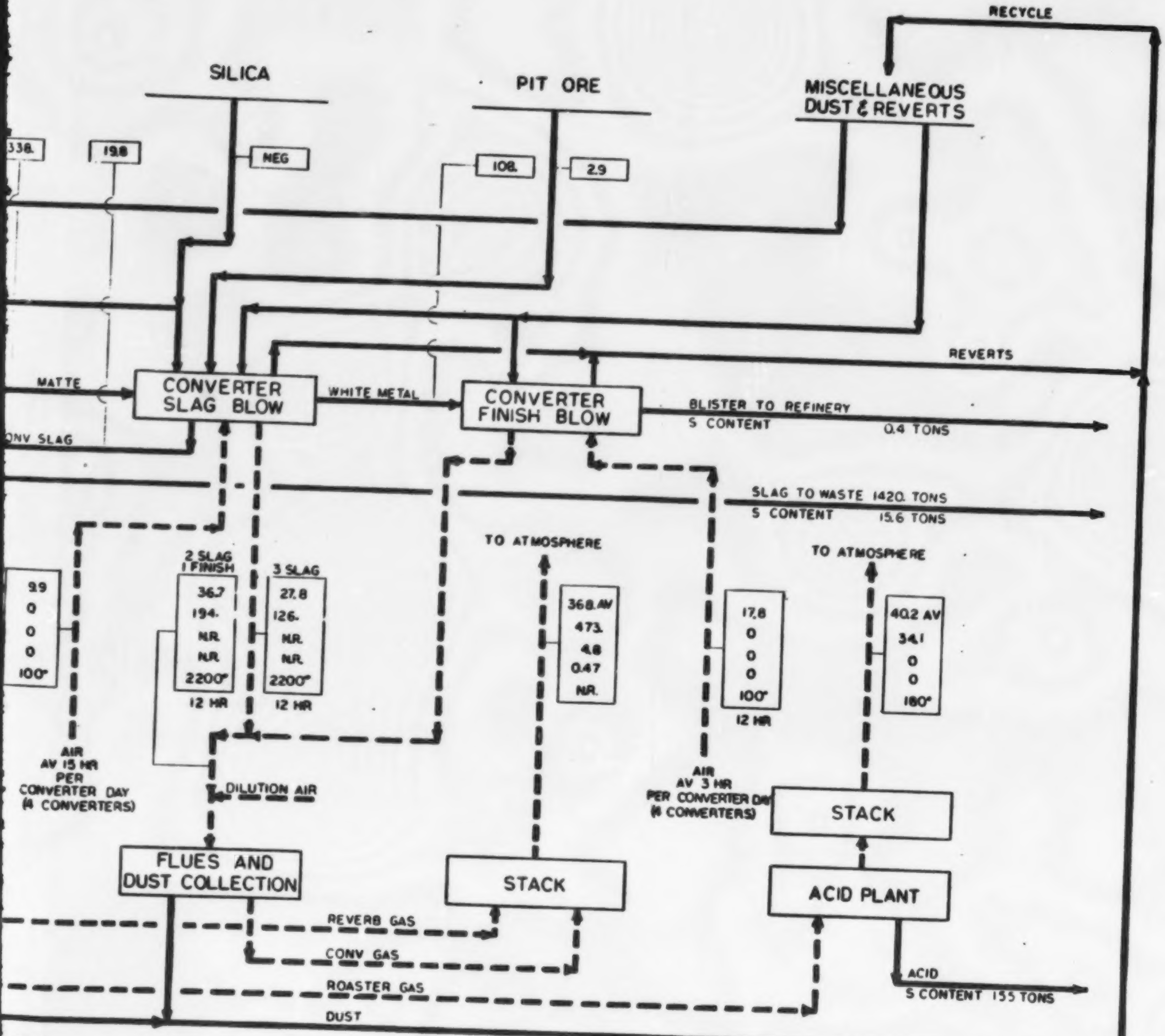
B

NATIONAL AIR POLLUTION CONTROL ADMINISTRATION	ARTHUR G. McKEE & COMPANY WESTERN KNAPP ENGINEERING DIVISION SAN FRANCISCO CALIFORNIA
326.05 COPPER PLANT FLOW DIAGRAM	ENG. DEPT. DWG. 10-01-006 PLATE NO. A-5


COPPER CONCENTRATE
LIMESTONE
COPPER PRECIPITATE
S TONS
283.
393.
NIL
94.
NEG
338.
19.8
NAT GAS FUEL
ROASTER
CALCINE + DUST
REVERBERATORY FURNACES
MATTE
C
S
CONV SLAG
AIR
1200°
2400°
ACTUAL TEMP °F
AIR PREHEATER
WASTE HEAT BOILERS
GAS 1000 SCFM
S IN GAS TONS
DUST TONS
S IN DUST TONS
ACTUAL TEMP °F
24.6*
189.
N.R.
N.R.
1200°
96.6
0
0
0
100°
155.
153.
N.R.
N.R.
700°
9.9
0
0
0
100°
COMBUSTION AIR
DILUTION AIR
AIR AV 15 HR PER CONVERTER DAY (4 CONVERTERS)
FLUES AND DUST COLLECTION
FLUES AND DUST COLLECTION
F
DUST

KEY
SOLIDS & LIQUIDS ———
GASES — — —
SCFM MEASURED AT 32°F AND ONE ATMOSPHERE
NIL - NEGLECTED (INSIGNIFICANT QUANTITY NOT AFFECTING MATERIAL BALANCE)
NEG. - NEGLECTED (MINOR QUANTITY PRESENT, BUT NOT REPORTED OR ESTIMATED)
N.R. - NOT REPORTED (QUANTITY UNKNOWN)
* - ESTIMATED QUANTITY

NOTE:
ALTHOUGH SHOWN
BLOCKS THE SAM
IS USED FOR SL
BLOWS


RECYCLE
SILICA
PIT ORE
MISCELLANEOUS DUST & REVERTS
338.
19.8
NEG
10.8
2.9
MATTE
CONVERTER SLAG BLOW
WHITE METAL
CONVERTER FINISH BLOW
REVERTS
CONV SLAG
BLISTER TO REFINERY
S CONTENT 0.4 TONS
SLAG TO WASTE 1420. TONS
S CONTENT 15.6 TONS
TO ATMOSPHERE
TO ATMOSPHERE
9.9
0
0
0
100°
2 SLAG 1 FINISH
36.7
194.
N.R.
N.R.
2200°
12 HR
3 SLAG
27.8
126.
N.R.
N.R.
2200°
12 HR
368. AV
473.
4.8
0.47
N.R.
17.8
0
0
0
100°
12 HR
40.2 AV
34.1
0
0
180°
AIR AV 15 HR PER CONVERTER DAY (4 CONVERTERS)
DILUTION AIR
AIR AV 3 HR PER CONVERTER DAY (4 CONVERTERS)
STACK
FLUES AND DUST COLLECTION
STACK
ACID PLANT
REVERB GAS
CONV GAS
ROASTER GAS
DUST
ACID
S CONTENT 155 TONS

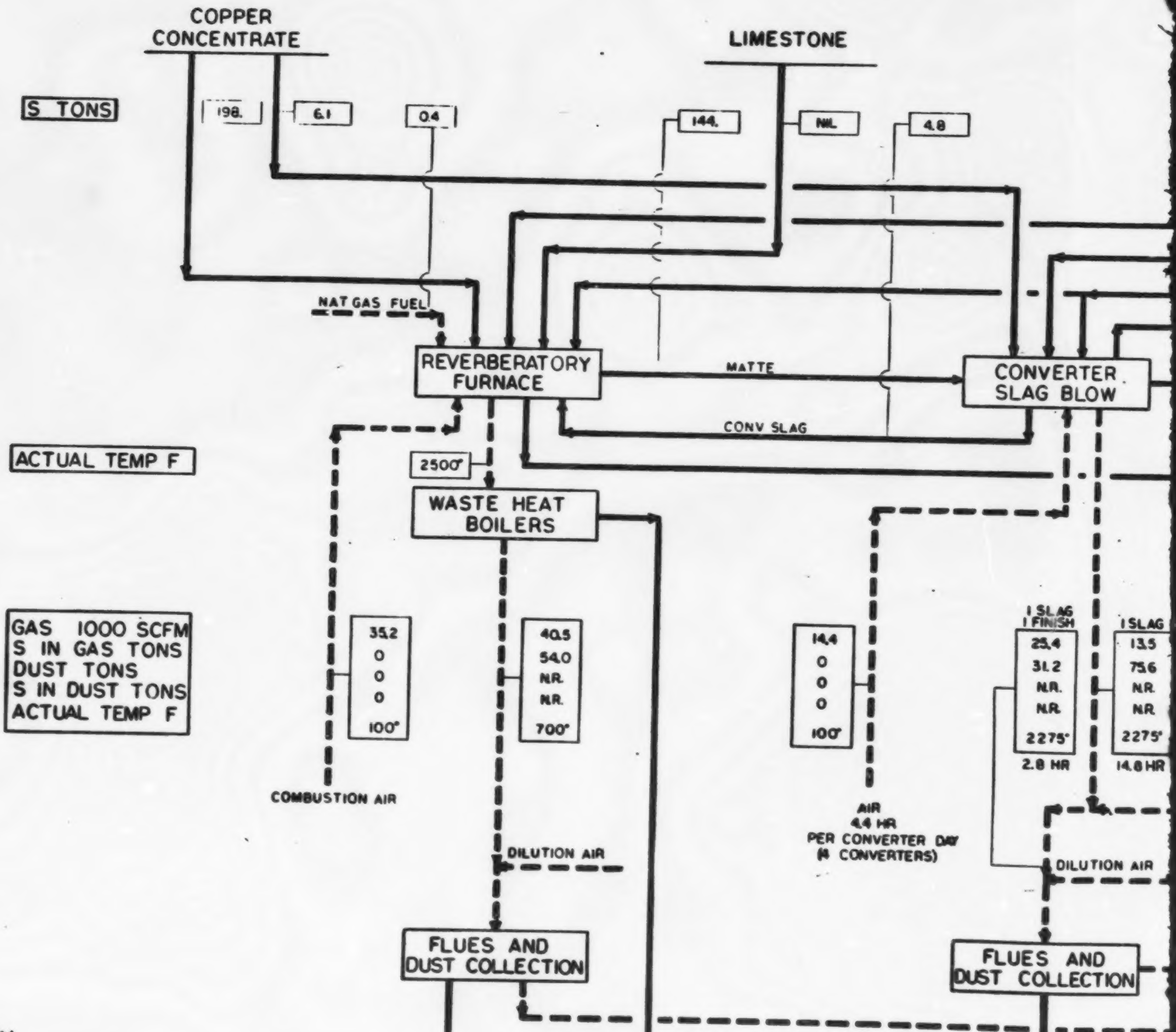
IOTE:
LTHOUGH SHOWN AS SEPARATE
LOCKS THE SAME CONVERTER
S USED FOR SLAG AND FINISH
LOWS

BASIS:
TONNAGES ARE GIVEN
FOR A 24-HOUR PERIOD
IN SHORT TONS

S-SULFUR

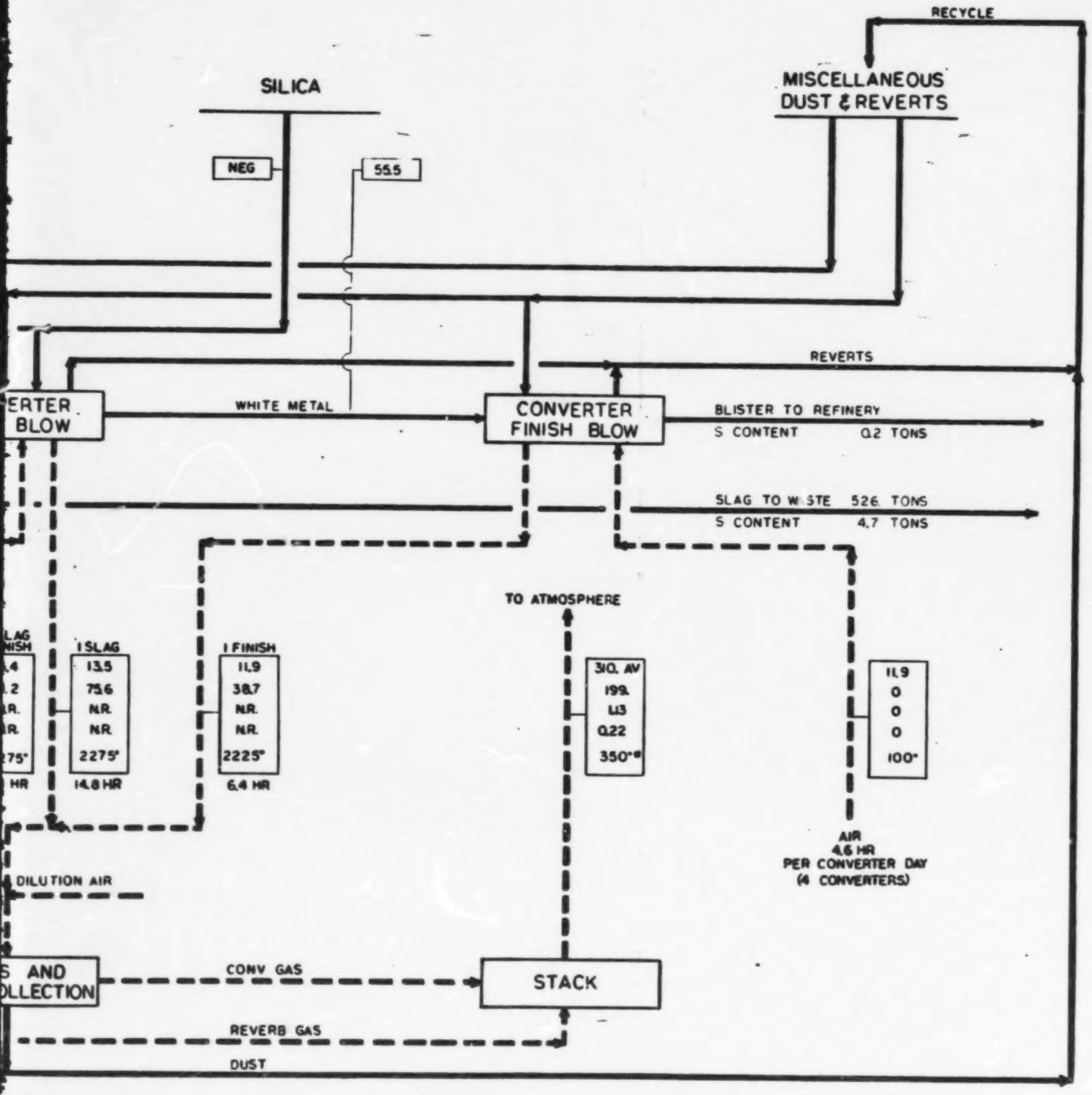
B

NATIONAL AIR POLLUTION CONTROL ADMINISTRATION	ARTHUR G. McKEE & COMPANY WESTERN KNAPP ENGINEERING DIVISION SAN FRANCISCO CALIFORNIA
326.06 COPPER PLANT FLOW DIAGRAM	ENG. DEPT. DWG. 10-01-007 PLATE NO. A-6


COPPER CONCENTRATE
LIMESTONE
S TONS
198.
6.1
0.4
144.
NIL
4.8
NAT GAS FUEL
REVERBERATORY FURNACE
MATTE
CONV SLAG
CONVERTER SLAG BLOW
ACTUAL TEMP F
2500°
WASTE HEAT BOILERS
GAS 1000 SCFM
S IN GAS TONS
DUST TONS
S IN DUST TONS
ACTUAL TEMP F
35.2
0
0
0
100°
40.5
54.0
N.R.
N.R.
700°
14.4
0
0
0
100°
1 SLAG 1 FINISH
25.4
31.2
N.R.
N.R.
2275°
2.8 HR
1 SLAG
13.5
75.6
N.R.
N.R.
2275°
14.8 HR
COMBUSTION AIR
AIR
4.4 HR
PER CONVERTER DAY
(4 CONVERTERS)
DILUTION AIR
DILUTION AIR
FLUES AND DUST COLLECTION
FLUES AND DUST COLLECTION

KEY
SOLIDS & LIQUIDS ———
GASES – – –
SCFM MEASURED AT 32°F AND ONE ATMOSPHERE
NIL - NEGLECTED (INSIGNIFICANT QUANTITY NOT AFFECTING MATERIAL BALANCE)
NEG. - NEGLECTED (MINOR QUANTITY PRESENT, BUT NOT REPORTED OR ESTIMATED)
N.R. - NOT REPORTED QUANTITY UNKNOWN
■ - ESTIMATED QUANTITY

NOTE:
ALTHOUGH SHO
BLOCKS THE S
IS USED FOR
BLOWS


RECYCLE
SILICA
MISCELLANEOUS DUST & REVERTS
NEG
55.5
REVERTS
ERTER BLOW
WHITE METAL
CONVERTER FINISH BLOW
BLISTER TO REFINERY
S CONTENT 0.2 TONS
SLAG TO WASTE 526. TONS
S CONTENT 4.7 TONS
TO ATMOSPHERE
LAG NISH
.4
.2
.R.
.R.
275°
HR
1 SLAG
13.5
75.6
N.R.
N.R.
2275°
14.8 HR
1 FINISH
11.9
38.7
N.R.
N.R.
2225°
6.4 HR
310. AV
199.
1.13
0.22
350°*
11.9
0
0
0
100°
AIR
4.6 HR
PER CONVERTER DAY
(4 CONVERTERS)
DILUTION AIR
S AND
OLLECTION
CONV GAS
STACK
REVERB GAS
DUST

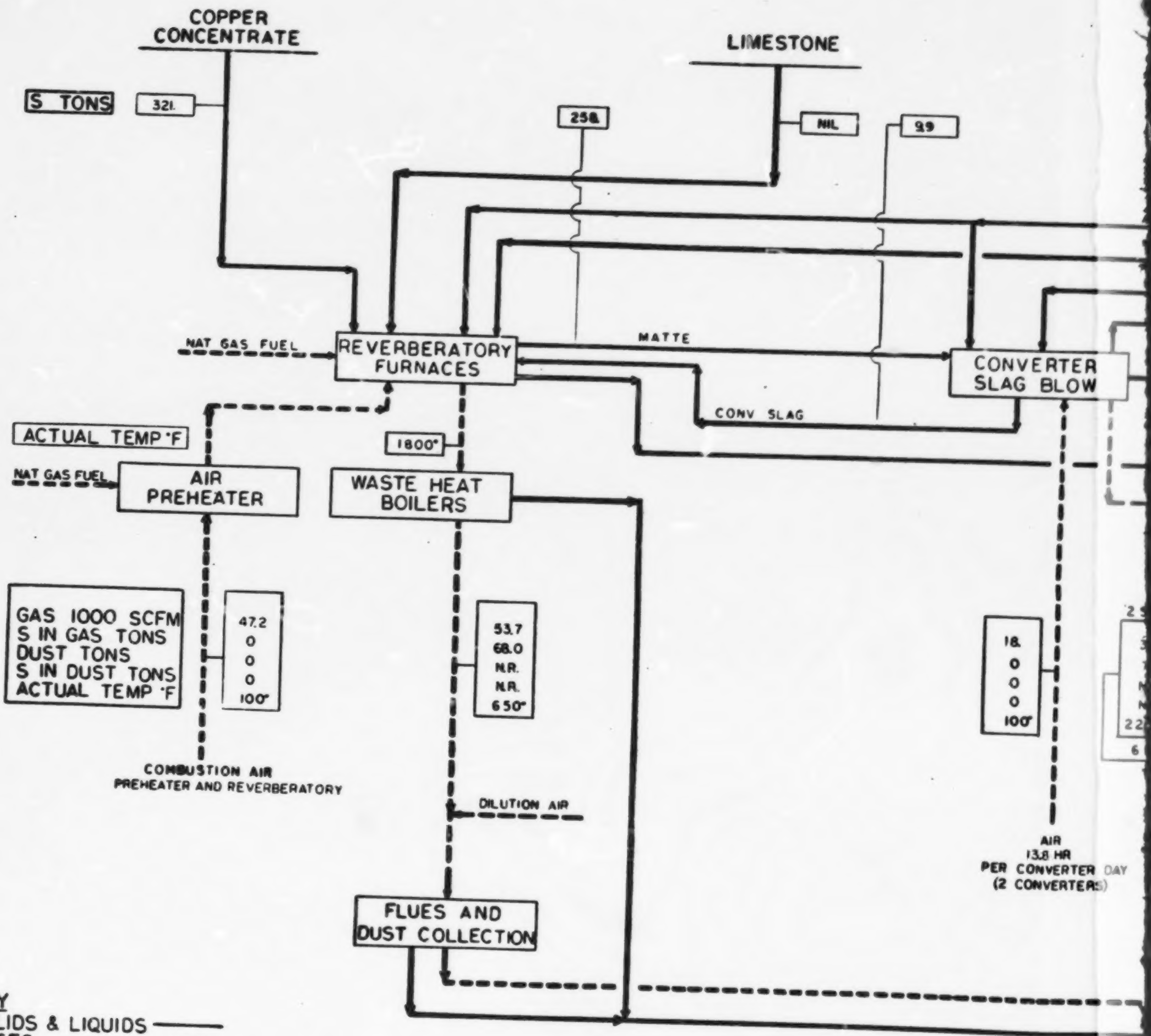
OTE:
LTHOUGH SHOWN AS SEPARATE
OCKS THE SAME CONVERTER
USED FOR SLAG AND FINISH
LOWS

BASIS:
TONNAGES ARE GIVEN
FOR A 24-HOUR PERIOD
IN SHORT TONS

S-SULFUR

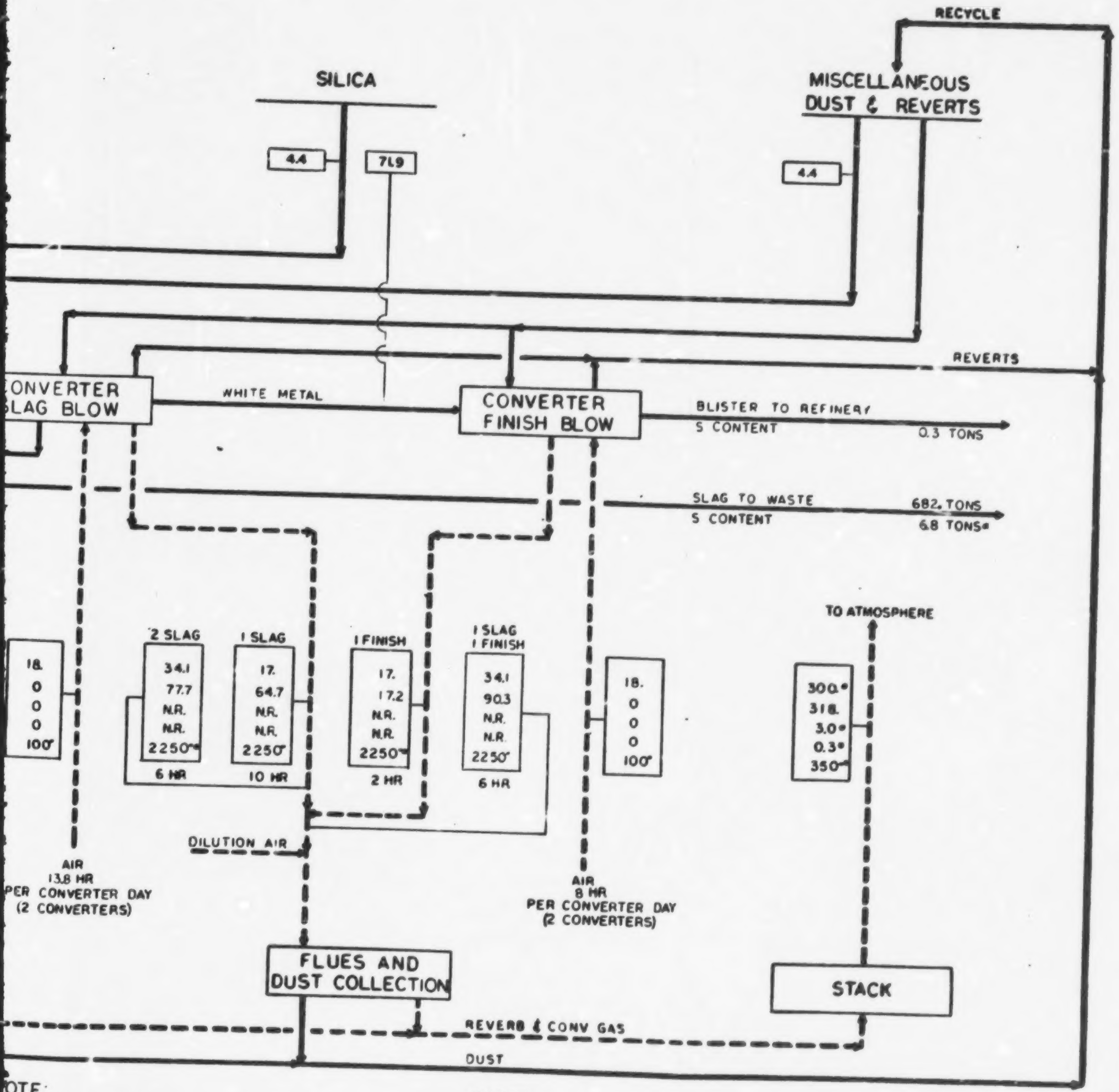
B

CLIENT	
NATIONAL AIR POLLUTION CONTROL ADMINISTRATION	ARTHUR G. McKEE & COMPANY WESTERN KNAPP ENGINEERING DIVISION SAN FRANCISCO CALIFORNIA
TITLE 326.07 COPPER PLANT FLOW DIAGRAM	ENG. DEPT. DWG. 10-01-008 PLATE NO. A-7


COPPER CONCENTRATE
S TONS
321.
LIMESTONE
258
NIL
29
NAT GAS FUEL
REVERBERATORY FURNACES
MATTE
CONVERTER SLAG BLOW
CONV SLAG
ACTUAL TEMP °F
1800°
NAT GAS FUEL
AIR PREHEATER
WASTE HEAT BOILERS
GAS 1000 SCFM
S IN GAS TONS
DUST TONS
S IN DUST TONS
ACTUAL TEMP °F
47.2
0
0
0
100°
53.7
68.0
N.R.
N.R.
650°
18.
0
0
0
100°
COMBUSTION AIR
PREHEATER AND REVERBERATORY
DILUTION AIR
AIR
13.8 HR
PER CONVERTER DAY
(2 CONVERTERS)
FLUES AND DUST COLLECTION

KEY
SOLIDS & LIQUIDS ———
GASES - - -
SCFM MEASURED AT 32°F AND ONE ATMOSPHERE
NIL - NEGLECTED (INSIGNIFICANT QUANTITY NOT AFFECTING MATERIAL BALANCE)
N.R. - NOT REPORTED (QUANTITY UNKNOWN)
* - ESTIMATED QUANTITY

NOTE:
ALTHOUGH SHOWN
BLOCKS THE SAM
IS USED FOR SLA
BLOWS


RECYCLE
SILICA
MISCELLANEOUS DUST & REVERTS
4.4
719
4.4
REVERTS
CONVERTER SLAG BLOW
WHITE METAL
CONVERTER FINISH BLOW
BLISTER TO REFINERY
S CONTENT
0.3 TONS
SLAG TO WASTE
682. TONS
S CONTENT
6.8 TONS*
TO ATMOSPHERE
18.
0
0
0
100°
2 SLAG
34.1
77.7
N.R.
N.R.
2250°
6 HR
1 SLAG
17.
64.7
N.R.
N.R.
2250°
10 HR
1 FINISH
17.
17.2
N.R.
N.R.
2250°
2 HR
1 SLAG 1 FINISH
34.1
90.3
N.R.
N.R.
2250°
6 HR
18.
0
0
0
100°
300.*
318.
3.0*
0.3*
350°
DILUTION AIR
AIR 13.8 HR PER CONVERTER DAY (2 CONVERTERS)
AIR 8 HR PER CONVERTER DAY (2 CONVERTERS)
FLUES AND DUST COLLECTION
STACK
REVERB & CONV GAS
DUST

OTE:
LTHOUGH SHOWN AS SEPARATE
LOCKS THE SAME CONVERTER
USED FOR SLAG AND FINISH
LOWS

BASIS:
TONNAGES ARE GIVEN
FOR A 24-HOUR PERIOD
IN SHORT TONS

S-SULFUR

B

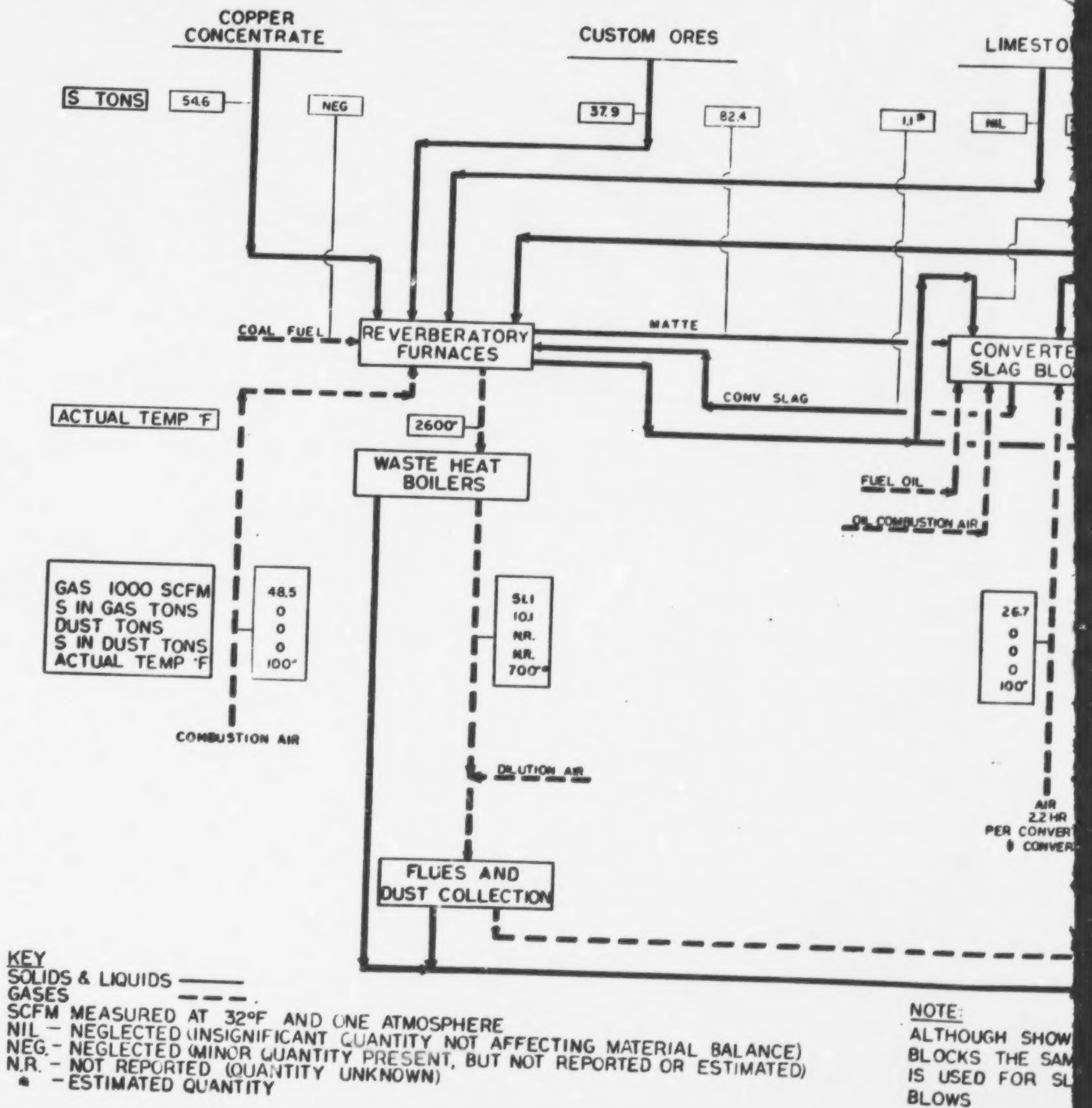
NATIONAL AIR
POLLUTION CONTROL
ADMINISTRATION

326.08
COPPER PLANT
FLOW DIAGRAM

ARTHUR G. McKEE & COMPANY
WESTERN KNAPP ENGINEERING DIVISION
SAN FRANCISCO CALIFORNIA

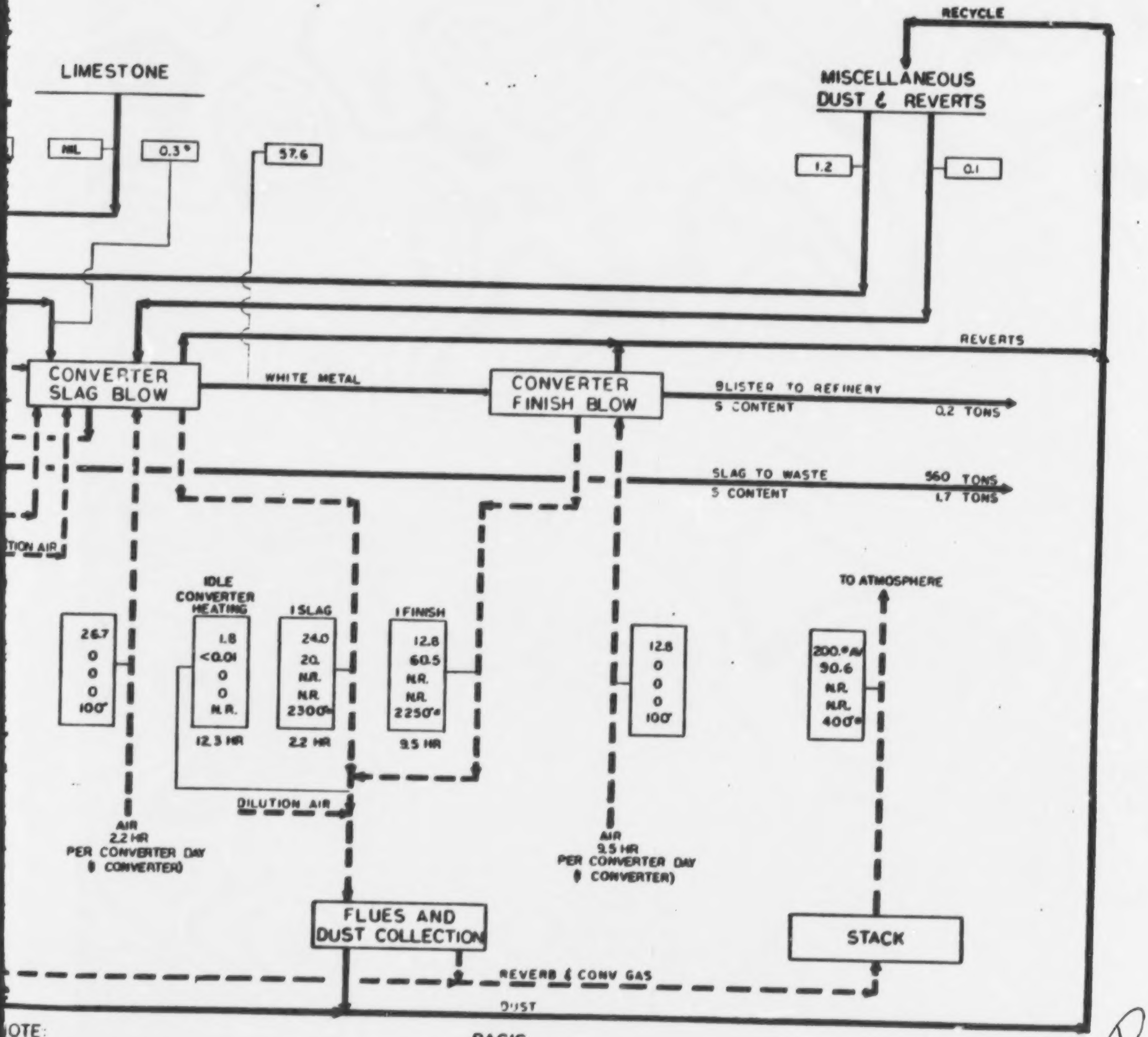
ENG. DEPT. DWG. 10-01-009

PLATE NO. A-8


COPPER CONCENTRATE
CUSTOM ORES
LIMESTO
S TONS
54.6
NEG
37.9
82.4
1.1*
NIL
COAL FUEL
REVERBERATORY FURNACES
MATTE
CONV SLAG
CONVERTE
SLAG BLO
ACTUAL TEMP °F
2600°
WASTE HEAT BOILERS
FUEL OIL
OIL COMBUSTION AIR
GAS 1000 SCFM
S IN GAS TONS
DUST TONS
S IN DUST TONS
ACTUAL TEMP °F
48.5
0
0
0
100°
51.1
10.1
N.R.
N.R.
700°*
26.7
0
0
0
100°
COMBUSTION AIR
DILUTION AIR
AIR
2.2 HR
PER CONVERT
CONVER
FLUES AND DUST COLLECTION

KEY
SOLIDS & LIQUIDS ———
GASES — — —
SCFM MEASURED AT 32°F AND ONE ATMOSPHERE
NIL – NEGLECTED (INSIGNIFICANT QUANTITY NOT AFFECTING MATERIAL BALANCE)
NEG. – NEGLECTED (MINOR QUANTITY PRESENT, BUT NOT REPORTED OR ESTIMATED)
N.R. – NOT REPORTED (QUANTITY UNKNOWN)
* – ESTIMATED QUANTITY

NOTE:
ALTHOUGH SHOW
BLOCKS THE SAM
IS USED FOR SL
BLOWS


RECYCLE
LIMESTONE
MISCELLANEOUS
DUST & REVERTS
NIL
0.3*
57.6
1.2
0.1
REVERTS
CONVERTER
SLAG BLOW
WHITE METAL
CONVERTER
FINISH BLOW
BLISTER TO REFINERY
S CONTENT
0.2 TONS
SLAG TO WASTE
S CONTENT
560 TONS
1.7 TONS
TION AIR
TO ATMOSPHERE
26.7
0
0
0
100°
IDLE
CONVERTER
HEATING
1.8
<0.01
0
0
N.R.
12.3 HR
1 SLAG
24.0
20.
N.R.
N.R.
2300°*
2.2 HR
1 FINISH
12.8
60.5
N.R.
N.R.
2250°*
9.5 HR
12.8
0
0
0
100°
200.*AV
90.6
N.R.
N.R.
400°*
DILUTION AIR
AIR
2.2 HR
PER CONVERTER DAY
(1 CONVERTER)
AIR
9.5 HR
PER CONVERTER DAY
(1 CONVERTER)
FLUES AND
DUST COLLECTION
STACK
REVERB & CONV GAS
DUST

IOTE:
LTHOUGH SHOWN AS SEPARATE
LOCKS THE SAME CONVERTER
S USED FOR SLAG AND FINISH
LOWS

BASIS:
TONNAGES ARE GIVEN
FOR A 24-HOUR PERIOD
IN SHORT TONS

S-SULFUR

B

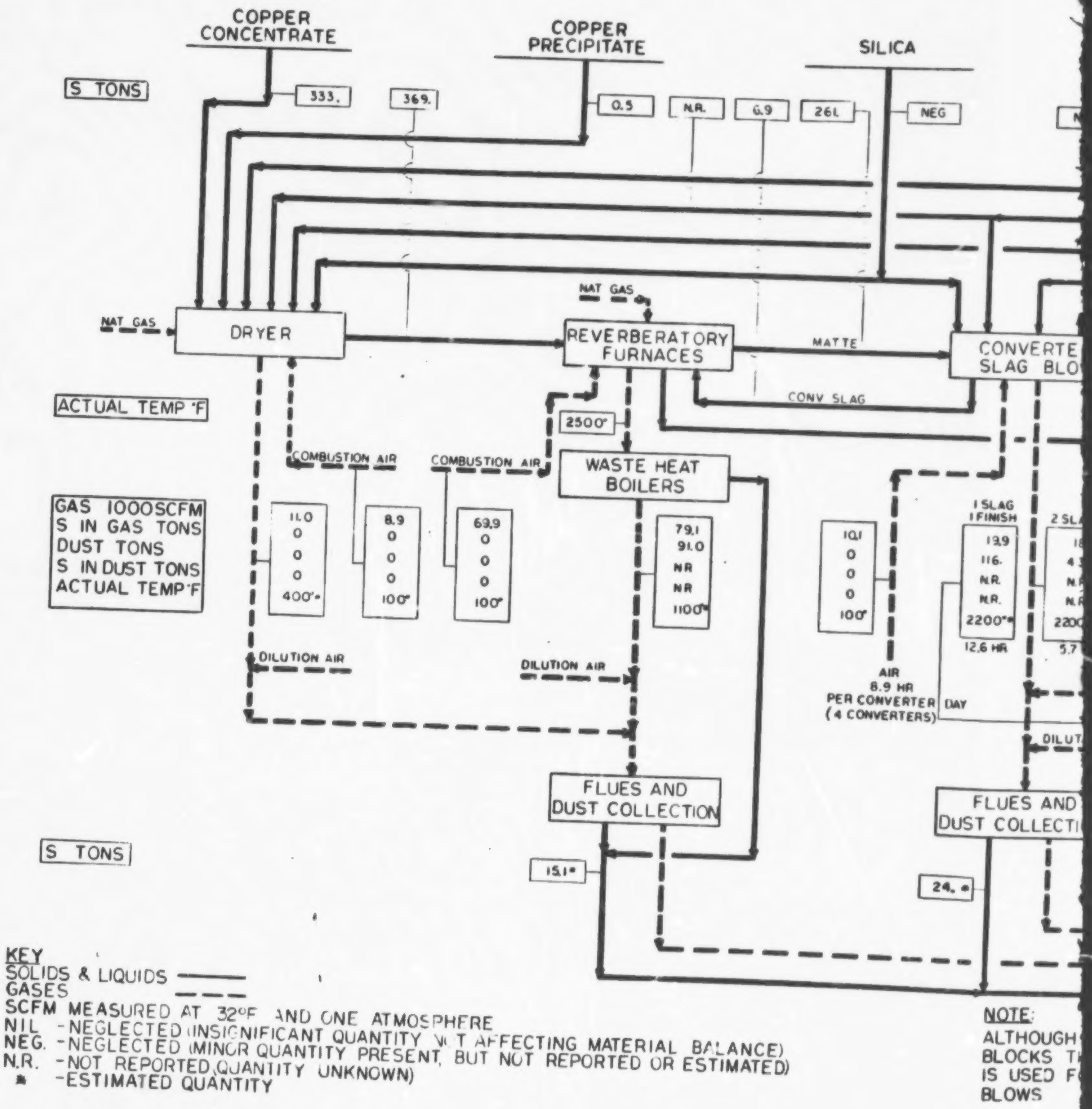
NATIONAL AIR
POLLUTION CONTROL
ADMINISTRATION

326.16
COPPER PLANT
FLOW DIAGRAM

ARTHUR G. McKEE & COMPANY
WESTERN KNAPP ENGINEERING DIVISION
SAN FRANCISCO CALIFORNIA

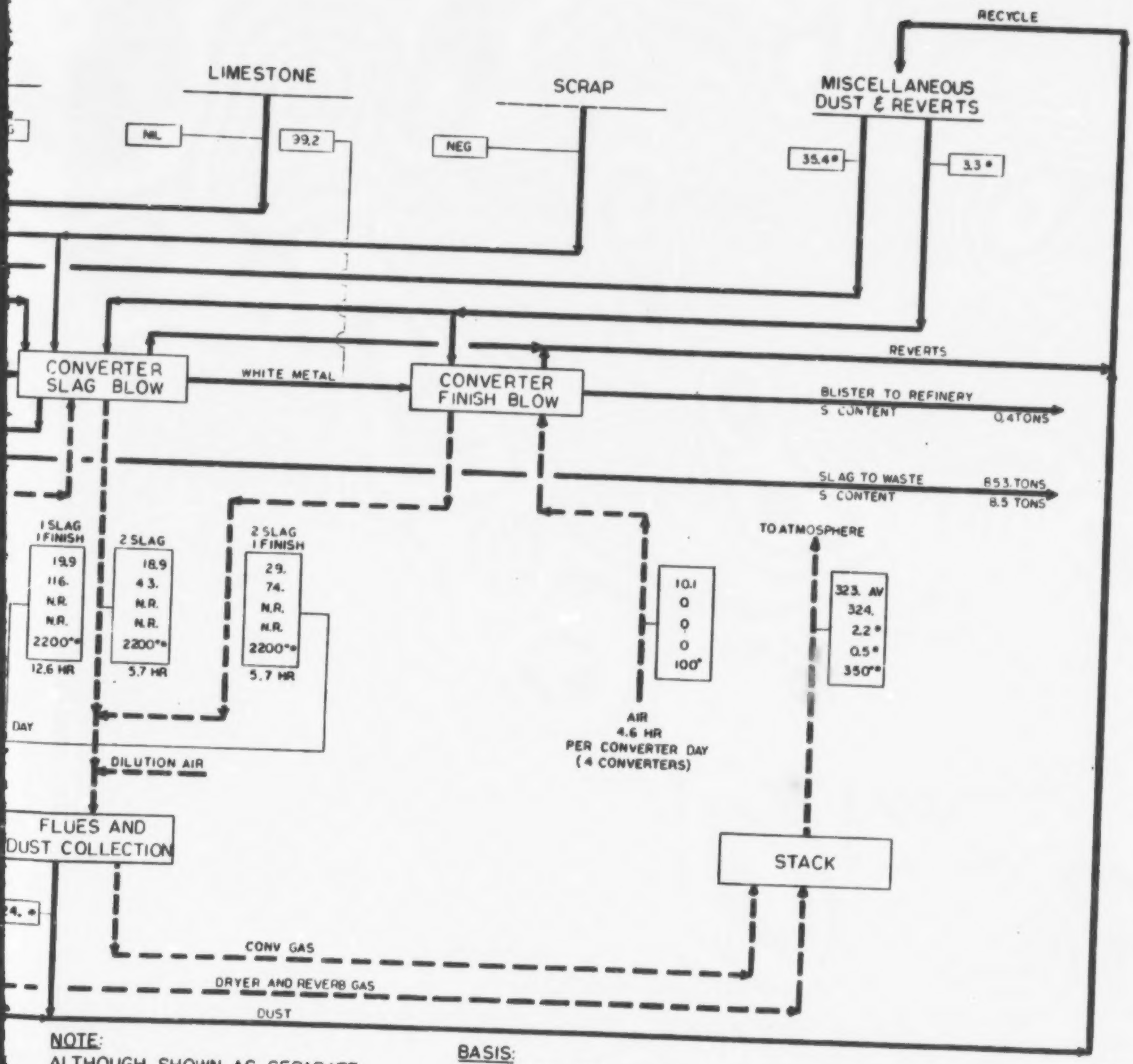
ENG. DEPT. DWG. 10-01-020

PLATE NO. A-9


COPPER CONCENTRATE
COPPER PRECIPITATE
SILICA
S TONS
333.
369.
0.5
N.R.
6.9
261.
NEG
NAT GAS
DRYER
NAT GAS
REVERBERATORY FURNACES
MATTE
CONVERTE
SLAG BLO
CONV SLAG
ACTUAL TEMP °F
2500°
COMBUSTION AIR
COMBUSTION AIR
WASTE HEAT BOILERS
GAS 1000SCFM
S IN GAS TONS
DUST TONS
S IN DUST TONS
ACTUAL TEMP °F
11.0 0 0 0 400°*
8.9 0 0 0 100°
69.9 0 0 0 100°
79.1 91.0 NR NR 1100°*
10.1 0 0 0 100°
1 SLAG 1 FINISH
13.9 116. N.R. N.R. 2200°* 12.6 HR
2 SLA
5.7
AIR
8.9 HR
PER CONVERTER DAY
(4 CONVERTERS)
DILUTION AIR
DILUTION AIR
DILUT
FLUES AND DUST COLLECTION
FLUES AND DUST COLLECTI
S TONS
15.1*
24.*

KEY
SOLIDS & LIQUIDS ———
GASES — — —
SCFM MEASURED AT 32°F AND ONE ATMOSPHERE
NIL -NEGLECTED (INSIGNIFICANT QUANTITY NOT AFFECTING MATERIAL BALANCE)
NEG. -NEGLECTED (MINOR QUANTITY PRESENT, BUT NOT REPORTED OR ESTIMATED)
N.R. -NOT REPORTED (QUANTITY UNKNOWN)
* -ESTIMATED QUANTITY

NOTE:
ALTHOUGH
BLOCKS T
IS USED F
BLOWS


RECYCLE
LIMESTONE
SCRAP
MISCELLANEOUS DUST & REVERTS
NIL
39.2
NEG
35.4*
3.3*
CONVERTER SLAG BLOW
WHITE METAL
CONVERTER FINISH BLOW
REVERTS
BLISTER TO REFINERY
S CONTENT
0.4 TONS
SLAG TO WASTE
S CONTENT
853. TONS
8.5 TONS
TO ATMOSPHERE
1 SLAG 1 FINISH
19.9
116.
N.R.
N.R.
2200°*
12.6 HR
2 SLAG
18.9
43.
N.R.
N.R.
2200°*
5.7 HR
2 SLAG 1 FINISH
29.
74.
N.R.
N.R.
2200°*
5.7 HR
10.1
0
0
0
100°
323. AV
324.
2.2*
0.5*
350°*
DAY
AIR
4.6 HR
PER CONVERTER DAY
(4 CONVERTERS)
DILUTION AIR
FLUES AND DUST COLLECTION
24.*
STACK
CONV GAS
DRYER AND REVERB GAS
DUST

NOTE:
ALTHOUGH SHOWN AS SEPARATE BLOCKS THE SAME CONVERTER IS USED FOR SLAG AND FINISH BLOWS

BASIS:
TONNAGES ARE GIVEN FOR A 24-HOUR PERIOD IN SHORT TONS

S-SULFUR

B

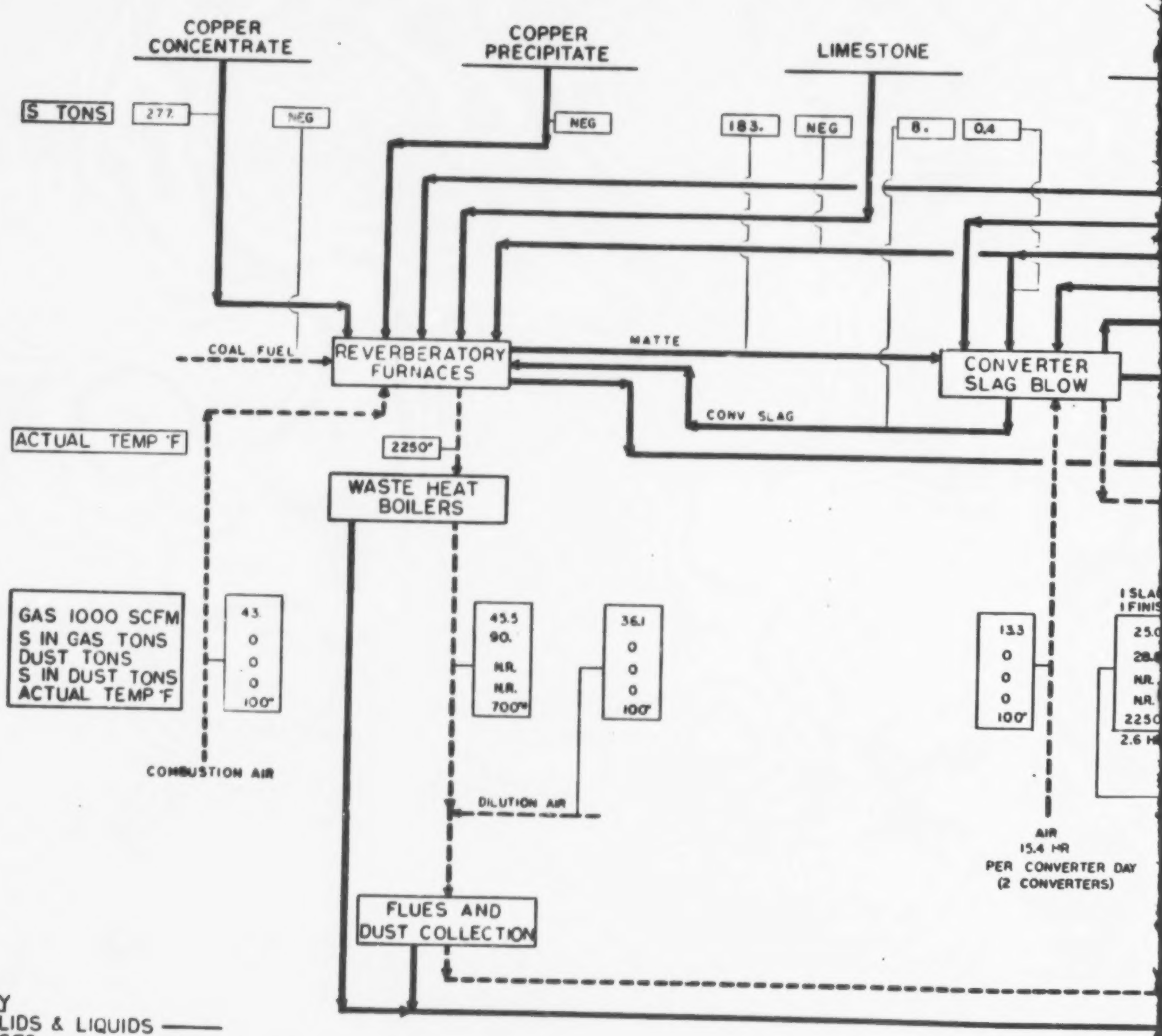
CLIENT
NATIONAL AIR
POLLUTION CONTROL
ADMINISTRATION

TITLE
326.20
COPPER PLANT
FLOW DIAGRAM

ARTHUR G. McKEE & COMPANY
WESTERN KNAPP ENGINEERING DIVISION
SAN FRANCISCO CALIFORNIA

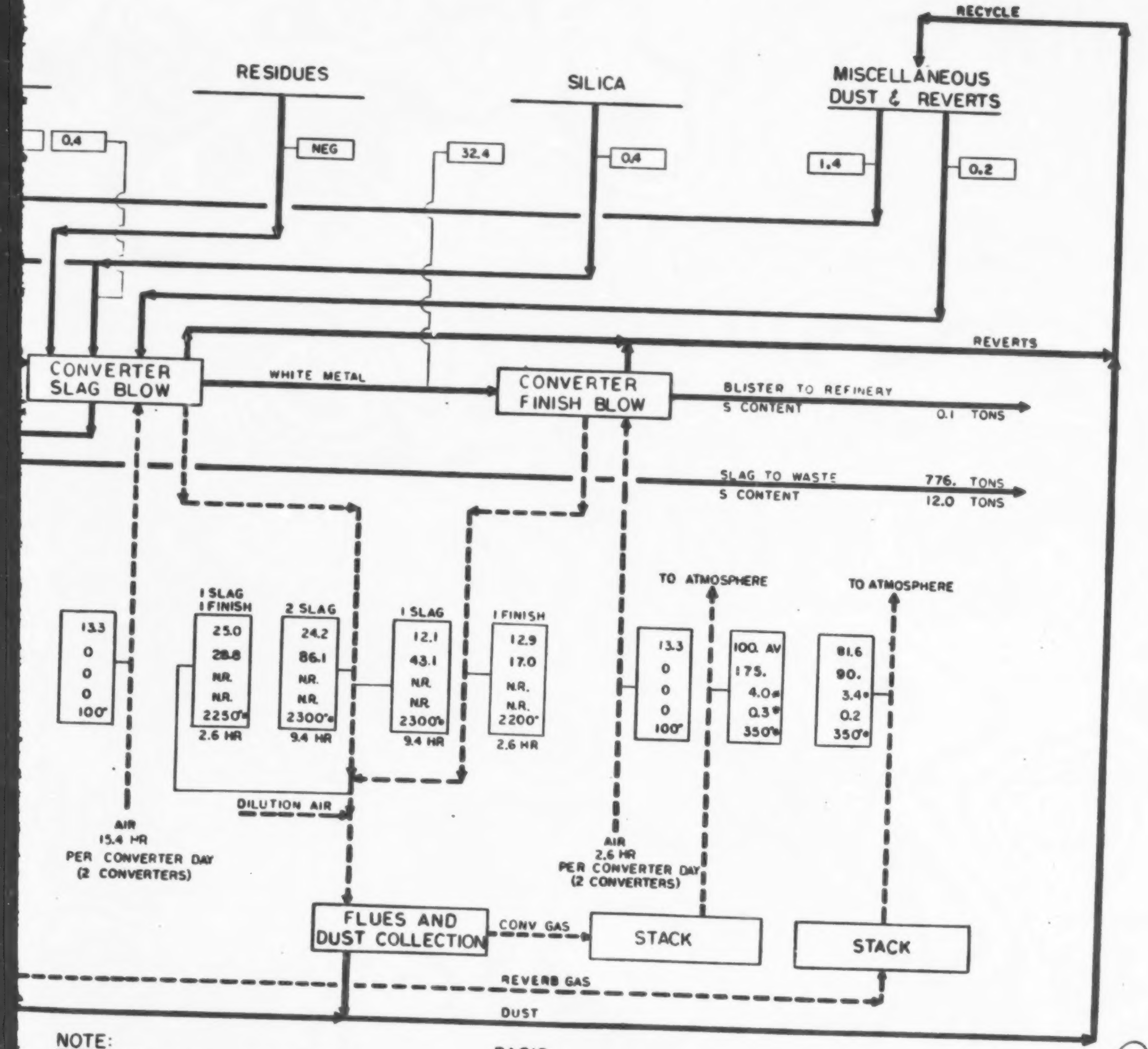
ENG. DEPT. DWG. 10-01-024

PLATE NO. A-10


COPPER CONCENTRATE
COPPER PRECIPITATE
LIMESTONE
S TONS
277.
NEG
NEG
183.
NEG
8.
0.4
COAL FUEL
REVERBERATORY FURNACES
MATTE
CONVERTER SLAG BLOW
CONV SLAG
ACTUAL TEMP °F
2250°
WASTE HEAT BOILERS
GAS 1000 SCFM
S IN GAS TONS
DUST TONS
S IN DUST TONS
ACTUAL TEMP °F
43.
0
0
0
100°
45.5
90.
N.R.
N.R.
700°*
36.1
0
0
0
100°
13.3
0
0
0
100°
1 SLA
1 FINIS
25.0
28.
N.R.
N.R.
2250
2.6 H
COMBUSTION AIR
DILUTION AIR
AIR
15.4 HR
PER CONVERTER DAY
(2 CONVERTERS)
FLUES AND DUST COLLECTION

KEY
SOLIDS & LIQUIDS ———
GASES – – –
SCFM MEASURED AT 32°F AND ONE ATMOSPHERE
NEG. - NEGLECTED (MINOR QUANTITY PRESENT, BUT NOT REPORTED OR ESTIMATED)
N.R. - NOT REPORTED (QUANTITY UNKNOWN)
* - ESTIMATED QUANTITY

NOTE:
ALTHOUGH SHOWN
BLOCKS THE SAM
IS USED FOR SL
BLOWS


RECYCLE
RESIDUES
SILICA
MISCELLANEOUS DUST & REVERTS
0.4
NEG
32.4
0.4
1.4
0.2
CONVERTER SLAG BLOW
WHITE METAL
CONVERTER FINISH BLOW
REVERTS
BLISTER TO REFINERY
S CONTENT 0.1 TONS
SLAG TO WASTE 776. TONS
S CONTENT 12.0 TONS
TO ATMOSPHERE
TO ATMOSPHERE
13.3
0
0
0
100°
1 SLAG 1 FINISH
25.0
28.8
N.R.
N.R.
2250°
2.6 HR
2 SLAG
24.2
86.1
N.R.
N.R.
2300°
9.4 HR
1 SLAG
12.1
43.1
N.R.
N.R.
2300°
9.4 HR
1 FINISH
12.9
17.0
N.R.
N.R.
2200°
2.6 HR
13.3
0
0
0
100°
100. AV
175.
4.0
0.3
350°
81.6
90.
3.4
0.2
350°
DILUTION AIR
AIR 15.4 HR PER CONVERTER DAY (2 CONVERTERS)
AIR 2.6 HR PER CONVERTER DAY (2 CONVERTERS)
FLUES AND DUST COLLECTION
CONV GAS
STACK
STACK
REVERB GAS
DUST

NOTE:
ALTHOUGH SHOWN AS SEPARATE BLOCKS THE SAME CONVERTER IS USED FOR SLAG AND FINISH BLOWS

BASIS:
TONNAGES ARE GIVEN FOR A 24-HOUR PERIOD IN SHORT TONS

S-SULFUR

B

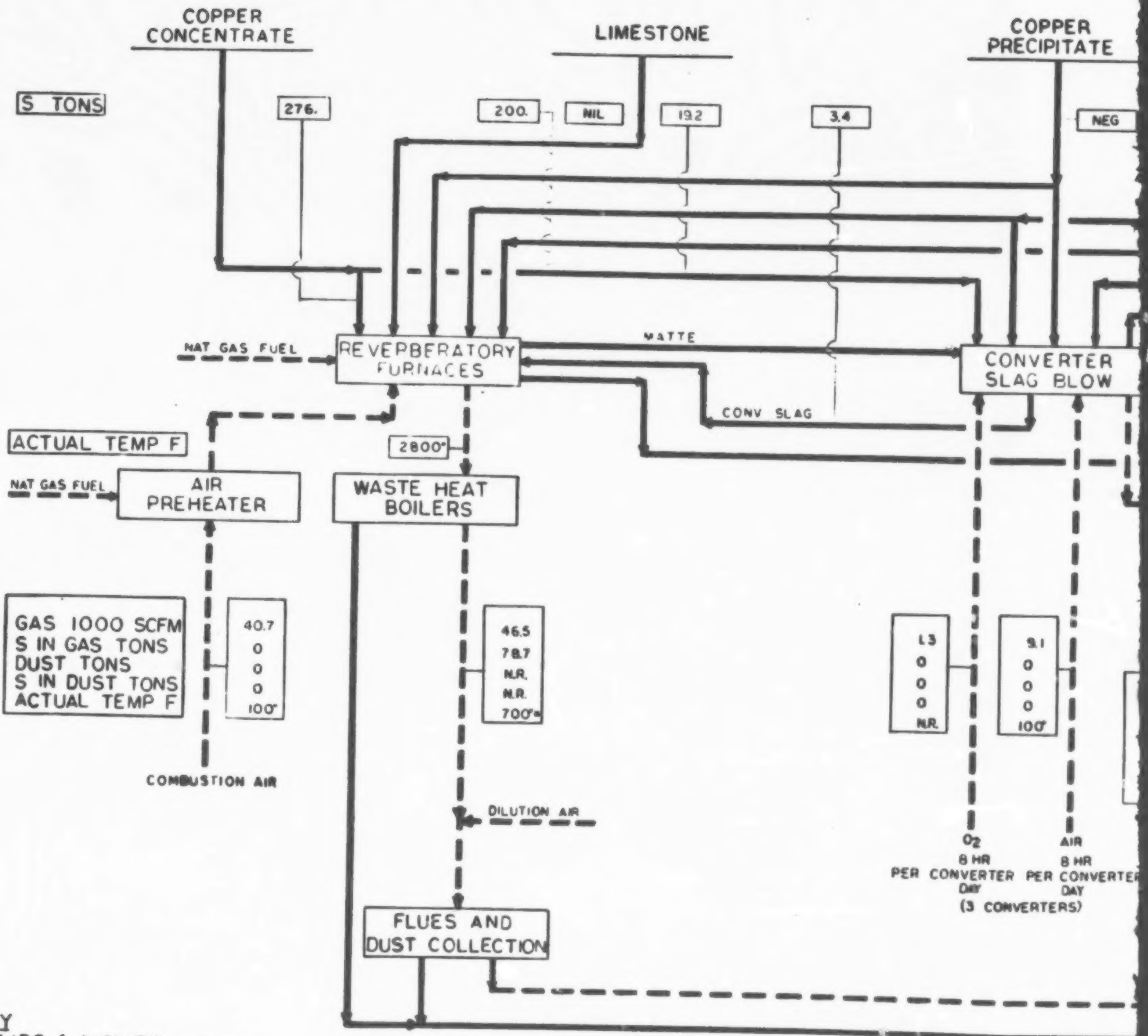
NATIONAL AIR
POLLUTION CONTROL
ADMINISTRATION

326.22
COPPER PLANT
FLOW DIAGRAM

ARTHUR G. McKEE & COMPANY
WESTERN KNAPP ENGINEERING DIVISION
SAN FRANCISCO CALIFORNIA

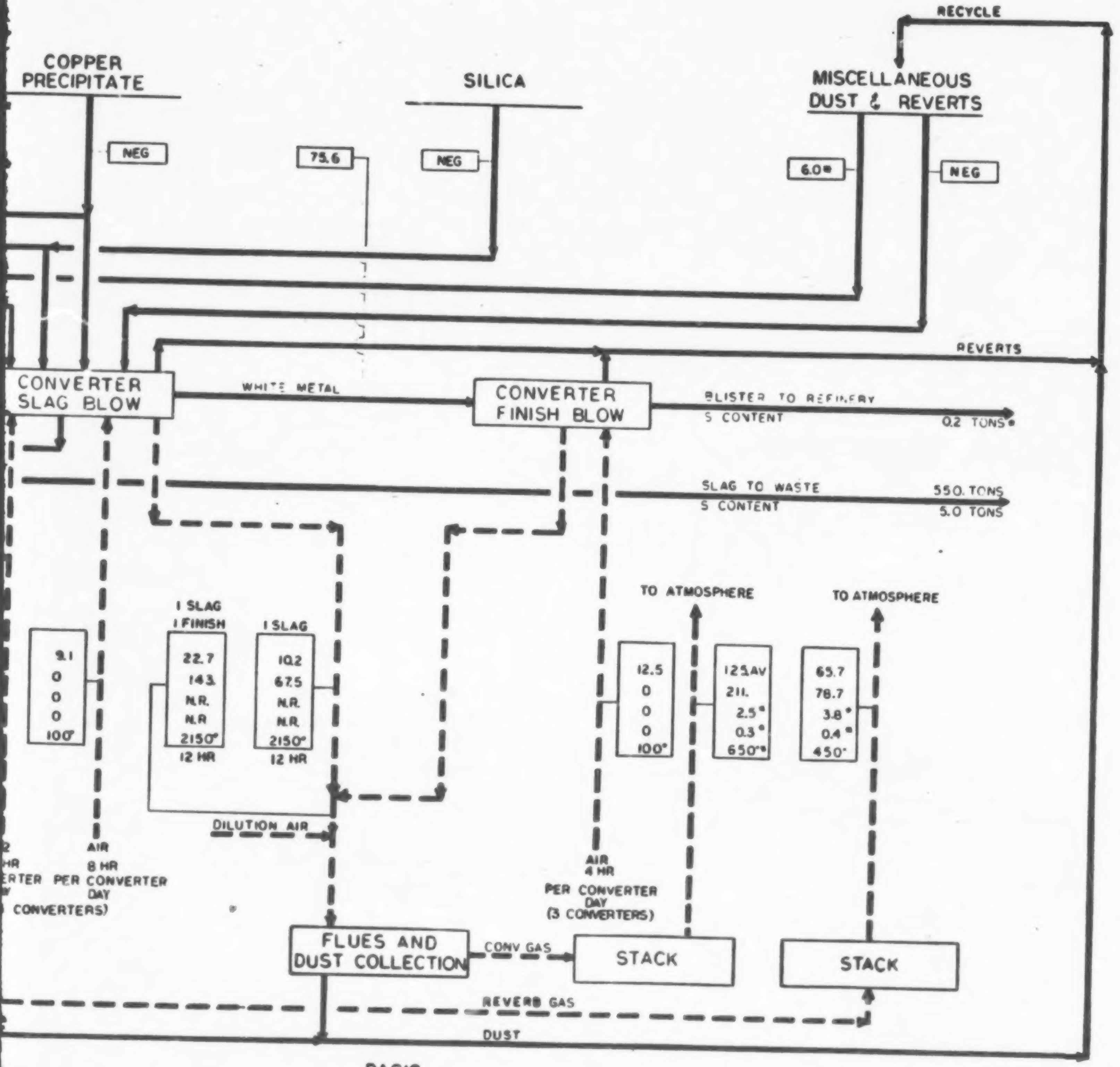
ENG. DEPT. DWG. 10-01-027

PLATE NO. A-11


COPPER CONCENTRATE
LIMESTONE
COPPER PRECIPITATE
S TONS
276.
200.
NIL
19.2
3.4
NEG
NAT GAS FUEL
REVERBERATORY FURNACES
MATTE
CONVERTER SLAG BLOW
CONV SLAG
ACTUAL TEMP F
2800°
NAT GAS FUEL
AIR PREHEATER
WASTE HEAT BOILERS
GAS 1000 SCFM
S IN GAS TONS
DUST TONS
S IN DUST TONS
ACTUAL TEMP F
40.7
0
0
0
100°
46.5
78.7
N.R.
N.R.
700°*
1.3
0
0
0
N.R.
9.1
0
0
0
100°
COMBUSTION AIR
DILUTION AIR
O2
8 HR
PER CONVERTER DAY
AIR
8 HR
PER CONVERTER DAY
(3 CONVERTERS)
FLUES AND DUST COLLECTION

KEY
SOLIDS & LIQUIDS ————
GASES — — —
SCFM MEASURED AT 32°F AND ONE ATMOSPHERE
NIL - NEGLECTED (INSIGNIFICANT QUANTITY NOT AFFECTING MATERIAL BALANCE)
NEG. - NEGLECTED MINOR QUANTITY PRESENT BUT NOT REPORTED OR ESTIMATED)
N.R. - NOT REPORTED (QUANTITY UNKNOWN)
* - ESTIMATED QUANTITY

NOTE:
ALTHOUGH SHOWN AS SEPARAT
BLOCKS THE SAME CONVERTER
IS USED FOR SLAG AND FINISH
BLOWS


RECYCLE
COPPER PRECIPITATE
SILICA
MISCELLANEOUS DUST & REVERTS
NEG
75.6
NEG
6.0*
NEG
CONVERTER SLAG BLOW
WHITE METAL
CONVERTER FINISH BLOW
REVERTS
BLISTER TO REFINERY
S CONTENT
0.2 TONS*
SLAG TO WASTE
S CONTENT
550. TONS
5.0 TONS
TO ATMOSPHERE
TO ATMOSPHERE
9.1
0
0
0
100°
1 SLAG
1 FINISH
22.7
143.
N.R.
N.R
2150°
12 HR
1 SLAG
10.2
67.5
N.R.
N.R.
2150°
12 HR
12.5
0
0
0
100°
125AV
211.
2.5*
0.3*
650°*
65.7
78.7
3.8*
0.4*
450°
DILUTION AIR
2
HR
ERTER PER
AIR
8 HR
CONVERTER
DAY
CONVERTERS)
AIR
4 HR
PER CONVERTER
DAY
(3 CONVERTERS)
FLUES AND DUST COLLECTION
CONV GAS
STACK
STACK
REVERB GAS
DUST

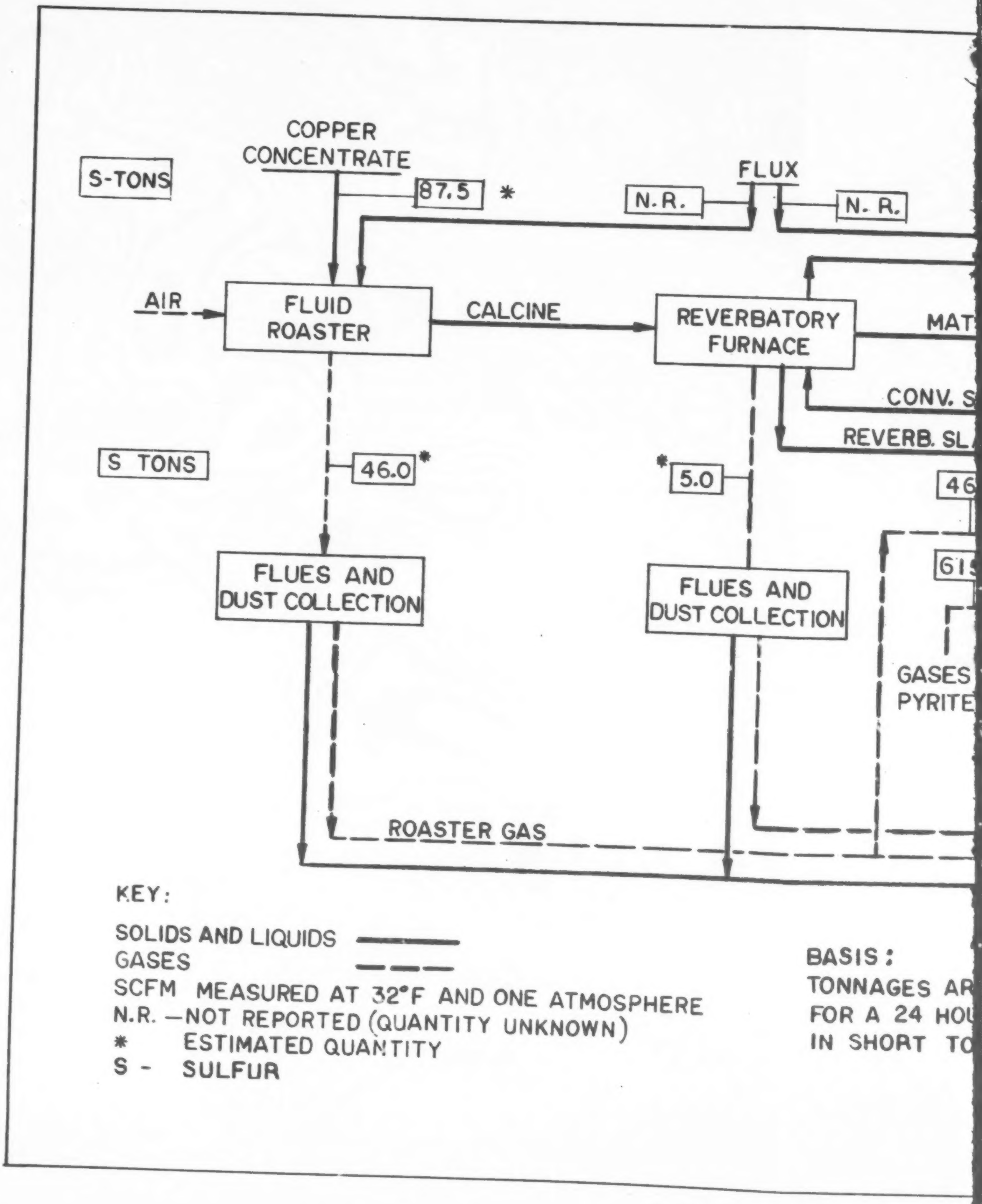
WN AS SEPARATE
AME CONVERTER
LAG AND FINISH

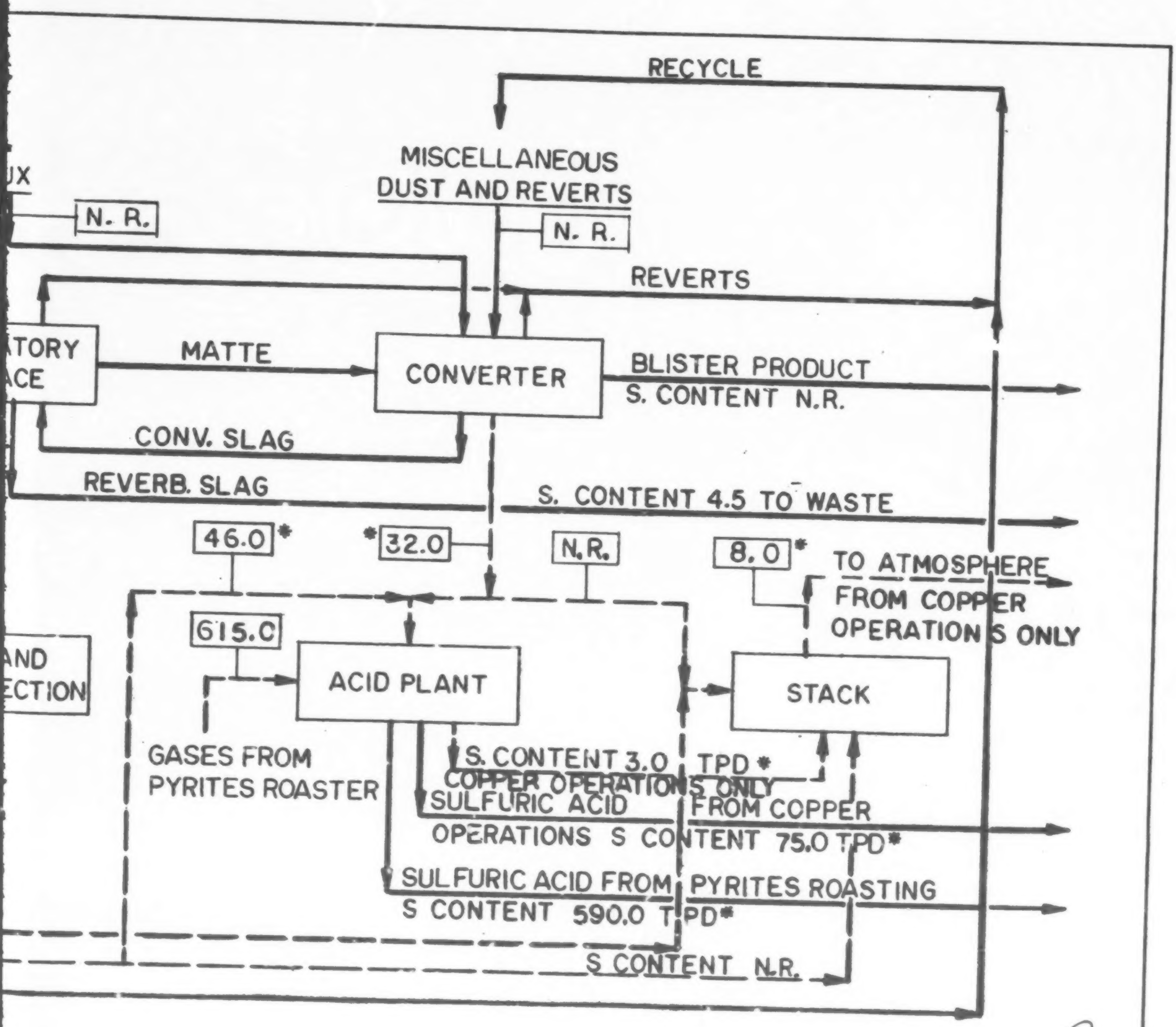
BASIS:
TONNAGES ARE GIVEN
FOR A 24-HOUR PERIOD
IN SHORT TONS

S-SULFUR

B

NATIONAL AIR POLLUTION CONTROL ADMINISTRATION	ARTHUR G. MCKEE & COMPANY WESTERN KNAPP ENGINEERING DIVISION SAN FRANCISCO CALIFORNIA
326.24 COPPER PLANT FLOW DIAGRAM	ENG. DEPT. DWG. 10-01-028 **PLATE NO. A-12**


S-TONS
COPPER CONCENTRATE
87.5 *
FLUX
N.R.
N. R.
AIR
FLUID ROASTER
CALCINE
REVERBATORY FURNACE
MAT
CONV. S
REVERB. SL
S TONS
46.0*
*5.0
46
61
FLUES AND DUST COLLECTION
FLUES AND DUST COLLECTION
GASES
PYRITE
ROASTER GAS
KEY:
SOLIDS AND LIQUIDS
GASES
SCFM MEASURED AT 32°F AND ONE ATMOSPHERE
N.R. —NOT REPORTED (QUANTITY UNKNOWN)
* ESTIMATED QUANTITY
S - SULFUR
BASIS:
TONNAGES AR
FOR A 24 HOU
IN SHORT TO


RECYCLE
UX
N. R.
MISCELLANEOUS DUST AND REVERTS
N. R.
REVERTS
ATORY
ACE
MATTE
CONVERTER
BLISTER PRODUCT
S. CONTENT N.R.
CONV. SLAG
REVERB. SLAG
S. CONTENT 4.5 TO WASTE
46.0*
*32.0
N.R.
8.0*
TO ATMOSPHERE FROM COPPER OPERATIONS ONLY
615.0
AND
ECTION
ACID PLANT
STACK
GASES FROM PYRITES ROASTER
S. CONTENT 3.0 TPD * COPPER OPERATIONS ONLY
SULFURIC ACID FROM COPPER OPERATIONS S CONTENT 75.0 TPD*
SULFURIC ACID FROM PYRITES ROASTING S CONTENT 590.0 TPD*
S CONTENT N.R.

B

BASIS:
TONNAGES ARE GIVEN
FOR A 24 HOUR PERIOD
IN SHORT TONS

CLIENT
NATIONAL AIR
POLLUTION CONTROL
ADMINISTRATION

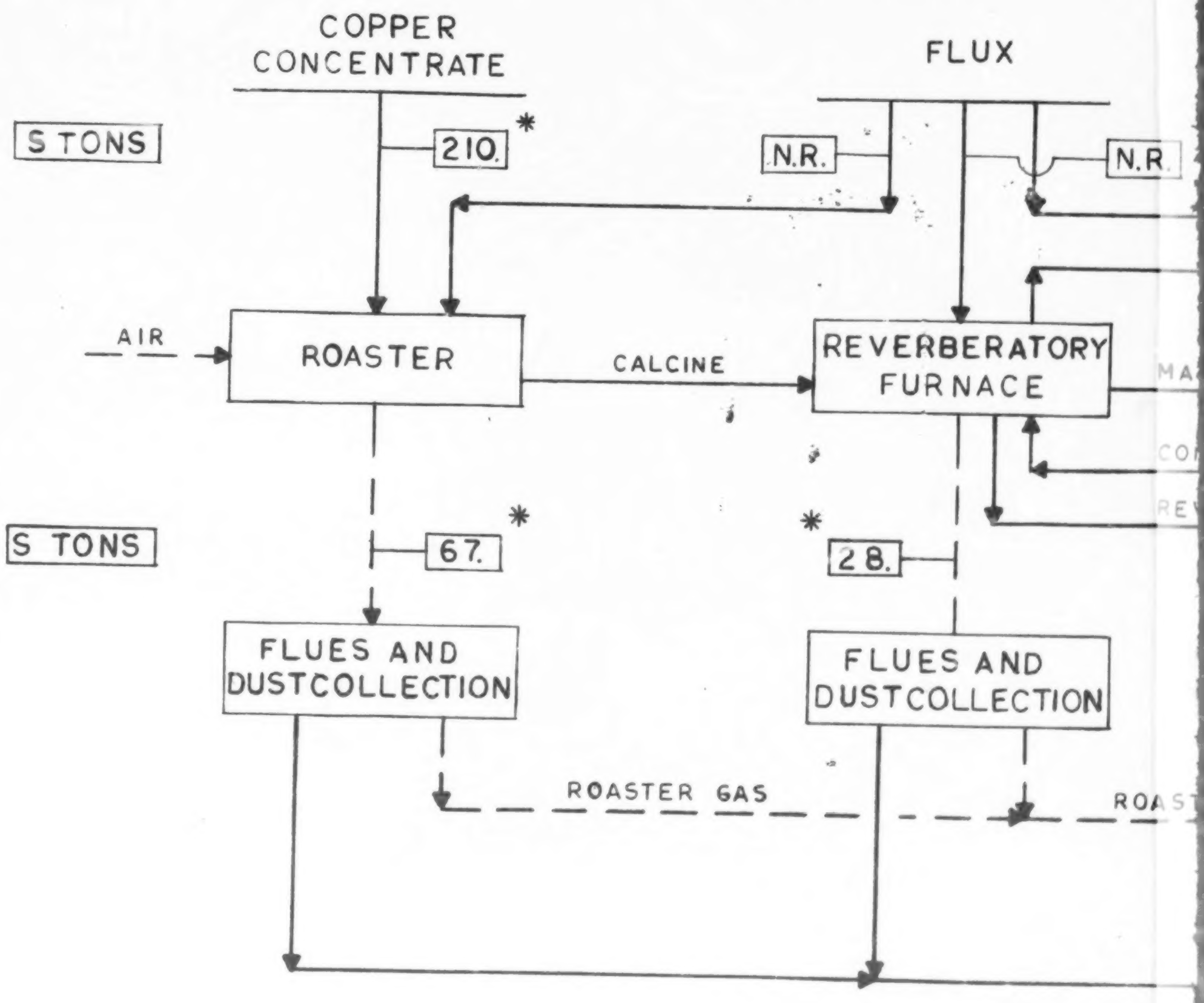
TITLE
326.30
COPPER PLANT
FLOW DIAGRAM

ARTHUR G. McKEE & COMPANY
WESTERN KNAPP ENGINEERING DIVISION
SAN FRANCISCO CALIFORNIA

ENG. DEPT. DWG. 10-01-041

PLATE NO. A-13

MATTE & SPEISS FROM DWG. 10-01-022


COPPER CONCENTRATE
FLUX
S TONS
210. *
N.R.
N.R.
AIR
ROASTER
CALCINE
REVERBERATORY FURNACE
MA
CO
REV
S TONS
67. *
* 28.
FLUES AND DUSTCOLLECTION
FLUES AND DUSTCOLLECTION
ROASTER GAS
ROAS

BASIC:

TONNAGES ARE GIVEN FOR A 24-HOUR PERIOD IN SHORT TONS

S-SULFUR

KEY:

N.R.-NOT REPORTED (QUAN

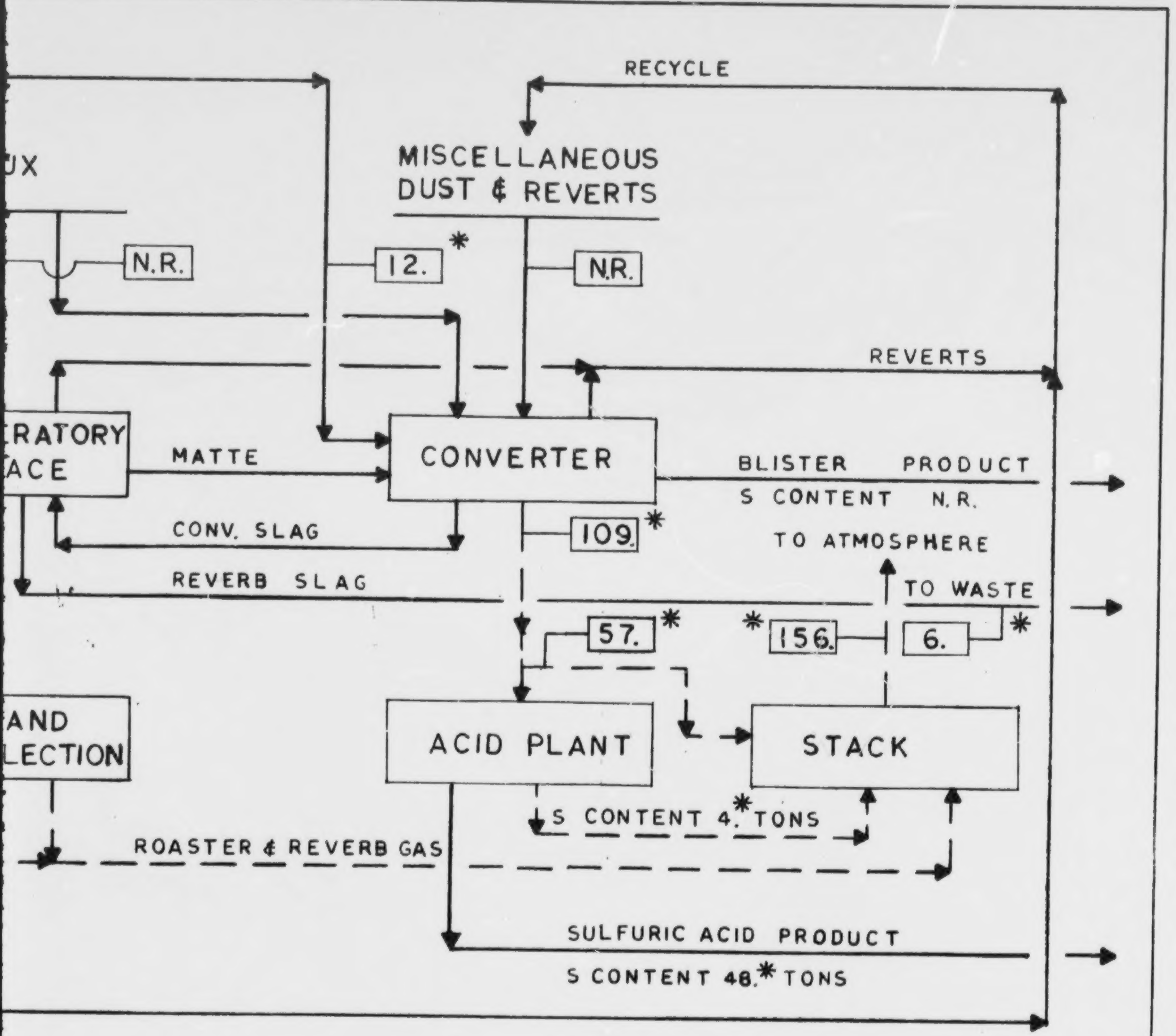
SOLIDS & LIQUIDS ———

GASES — — —

SCFM MEASURED AT 32°F

ONE ATMOSPHERE

* ESTIMATED QUANTITY


RECYCLE
UX
MISCELLANEOUS DUST & REVERTS
N.R.
12. *
N.R.
REVERTS
ERATORY
ACE
MATTE
CONVERTER
BLISTER PRODUCT
S CONTENT N.R.
CONV. SLAG
109. *
TO ATMOSPHERE
REVERB SLAG
TO WASTE
57. *
* 156.
6. *
AND
LECTION
ACID PLANT
STACK
S CONTENT 4.* TONS
ROASTER & REVERB GAS
SULFURIC ACID PRODUCT
S CONTENT 48.* TONS

RTED (QUANTITY UNKNOWN)
DS ————
— — — —
RED AT 32°F AND
HERE
QUANTITY

B

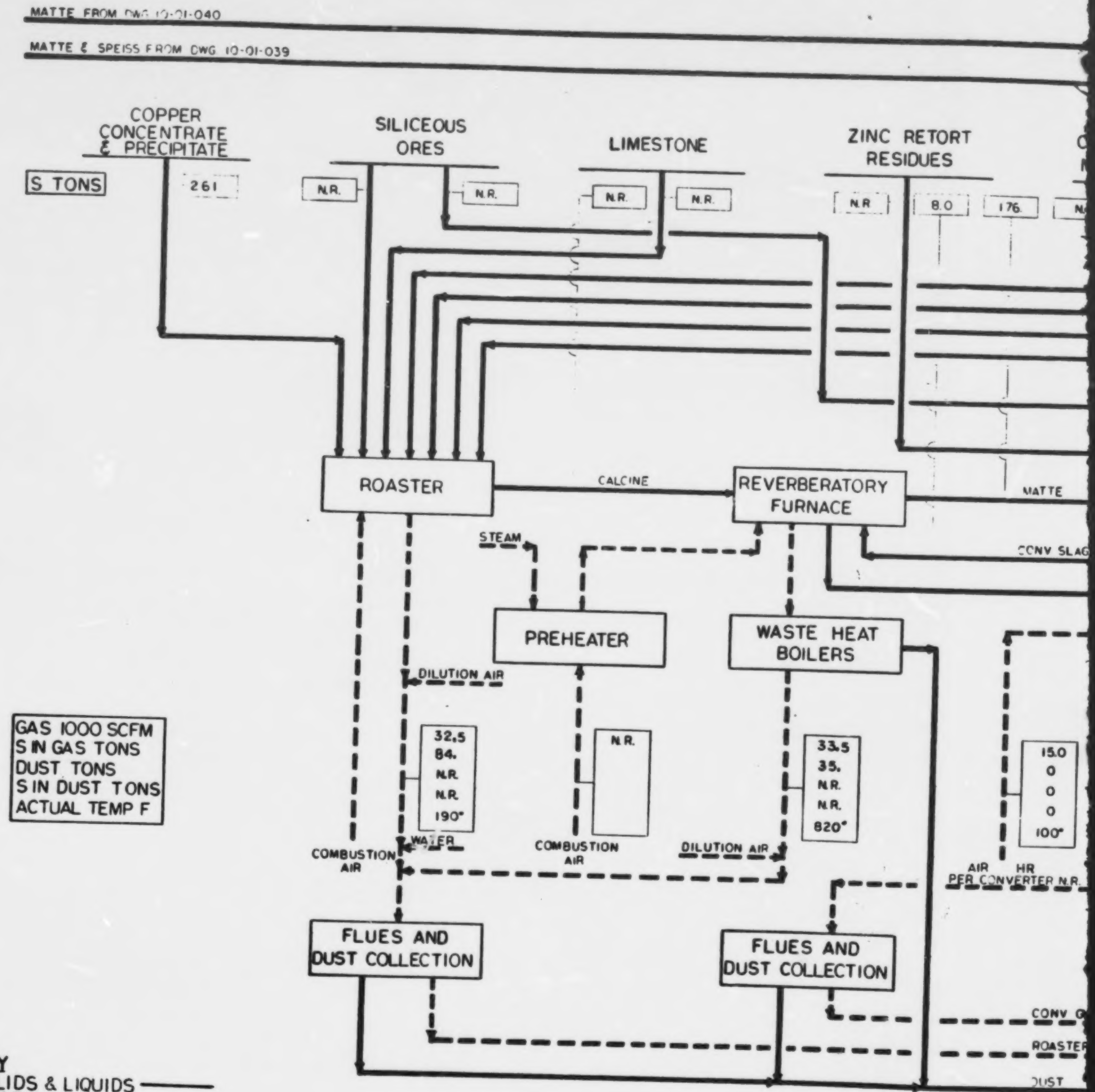
CLIENT
NATIONAL AIR
POLLUTION CONTROL
ADMINISTRATION

TITLE
326.36
COPPER PLANT
FLOW DIAGRAM

ARTHUR G. McKEE & COMPANY
WESTERN KNAPP ENGINEERING DIVISION
SAN FRANCISCO CALIFORNIA

ENG. DEPT. DWG. 10-01-046

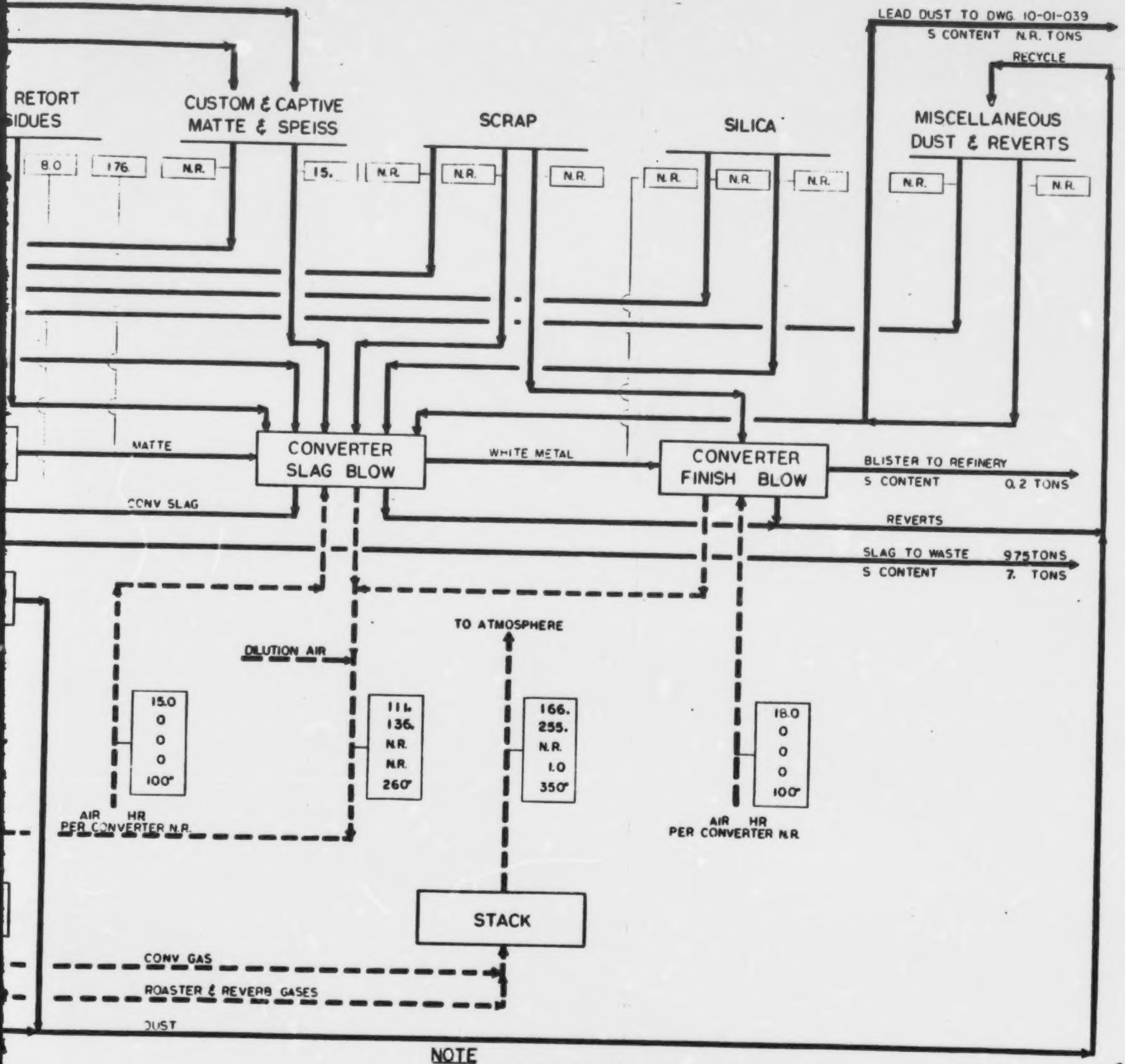
PLATE NO. A-14


MATTE FROM DWG 10-01-040
MATTE & SPEISS FROM DWG 10-01-039
COPPER CONCENTRATE & PRECIPITATE
S TONS
261
SILICEOUS ORES
N.R.
N.R.
LIMESTONE
N.R.
N.R.
ZINC RETORT RESIDUES
N.R
8.0
176.
ROASTER
CALCINE
REVERBERATORY FURNACE
MATTE
CONV SLAG
STEAM
PREHEATER
WASTE HEAT BOILERS
DILUTION AIR
GAS 1000 SCFM
S IN GAS TONS
DUST TONS
S IN DUST TONS
ACTUAL TEMP F
32.5
84.
N.R.
N.R.
190°
N.R.
33.5
35.
N.R.
N.R.
820°
15.0
0
0
0
100°
WATER
COMBUSTION AIR
COMBUSTION AIR
DILUTION AIR
AIR HR PER CONVERTER N.R.
FLUES AND DUST COLLECTION
FLUES AND DUST COLLECTION
CONV G
ROASTER
DUST

KEY
SOLIDS & LIQUIDS ———
GASES — — —
SCFM MEASURED AT 32°F AND ONE ATMOSPHERE
N.R. -NOT REPORTED (QUANTITY UNKNOWN)

BASIS:
TONNAGES ARE GIVEN
FOR A 24-HOUR PERIOD
IN SHORT TONS WHICH
ARE ESTIMATED FROM
PUBLISHED LITERATURE

S-SULFUR

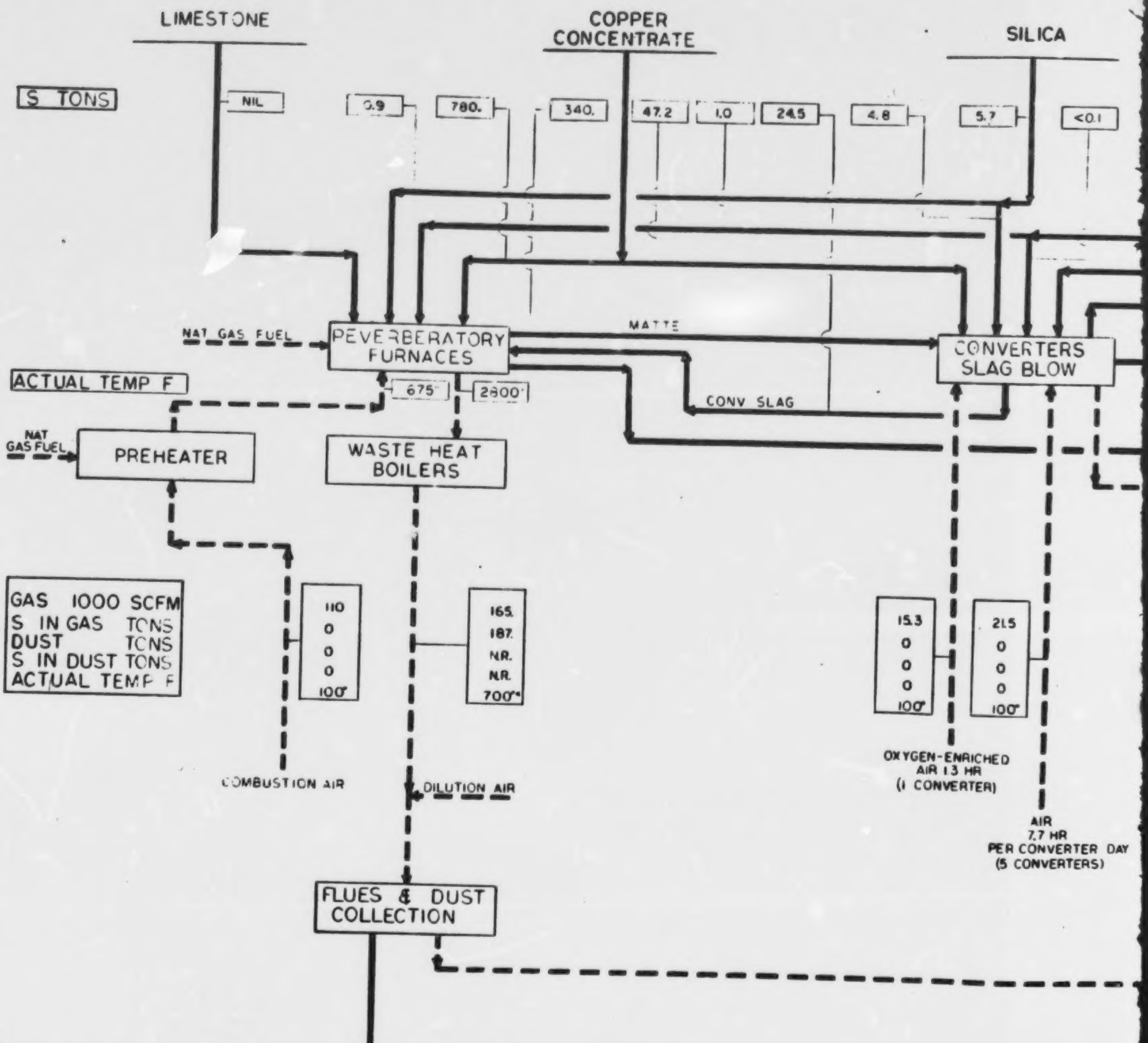

LEAD DUST TO DWG. 10-01-039
S CONTENT N.R. TONS
RECYCLE
RETORT
SIDUES
CUSTOM & CAPTIVE
MATTE & SPEISS
SCRAP
SILICA
MISCELLANEOUS
DUST & REVERTS
8.0
176.
N.R.
15.
N.R.
N.R.
N.R.
N.R.
N.R.
N.R.
N.R.
N.R.
MATTE
CONVERTER
SLAG BLOW
WHITE METAL
CONVERTER
FINISH BLOW
BLISTER TO REFINERY
S CONTENT 0.2 TONS
CONV SLAG
REVERTS
SLAG TO WASTE 975 TONS
S CONTENT 7. TONS
TO ATMOSPHERE
DILUTION AIR
15.0
0
0
0
100°
111.
136.
N.R.
N.R.
260°
166.
255.
N.R.
1.0
350°
18.0
0
0
0
100°
AIR HR
PER CONVERTER N.R.
AIR HR
PER CONVERTER N.R.
STACK
CONV GAS
ROASTER & REVERB GASES
DUST

NOTE
ALTHOUGH SHOWN AS SEPARATE BLOCKS THE SAME CONVERTER IS USED FOR SLAG AND FINISH BLOWS

B

E GIVEN
R PERIOD
NS WHICH
D FROM
TERATURE

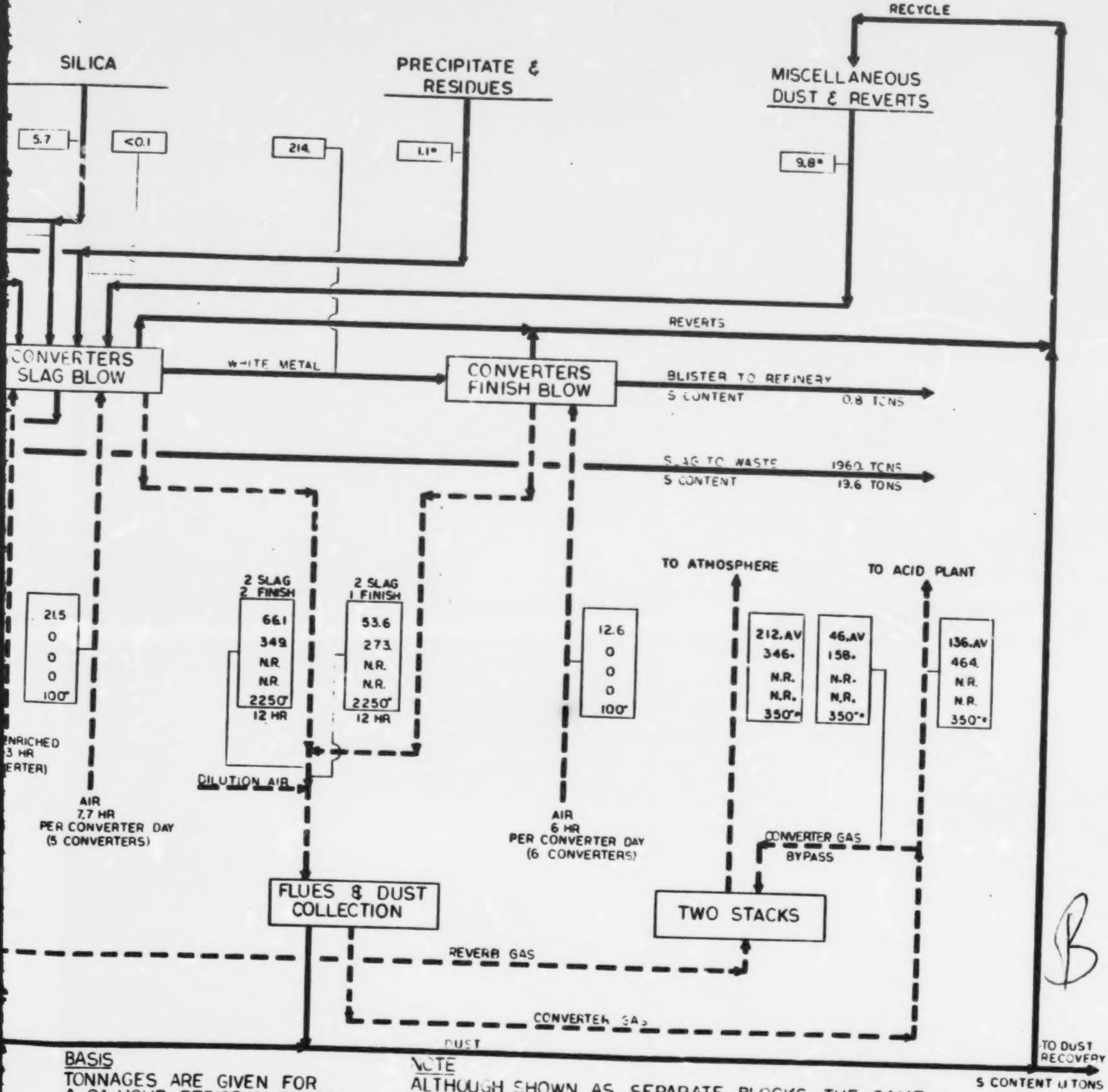
NATIONAL AIR POLLUTION CONTROL ADMINISTRATION	ARTHUR G. McKEE & COMPANY WESTERN KNAPP ENGINEERING DIVISION SAN FRANCISCO CALIFORNIA
326.33 COPPER PLANT FLOW DIAGRAM	ENG. DEPT. DWG. 10-01-041 **PLATE NO. A-15**


LIMESTONE
COPPER CONCENTRATE
SILICA
S TONS
NIL
0.9
780.
340.
47.2
1.0
24.5
4.8
5.7
<0.1
NAT GAS FUEL
REVERBERATORY FURNACES
MATTE
CONVERTERS SLAG BLOW
CONV SLAG
ACTUAL TEMP F
675°
2800°
NAT GAS FUEL
PREHEATER
WASTE HEAT BOILERS
GAS 1000 SCFM
S IN GAS TONS
DUST TONS
S IN DUST TONS
ACTUAL TEMP F
110
0
0
0
100°
165.
187.
N.R.
N.R.
700°*
15.3
0
0
0
100°
21.5
0
0
0
100°
COMBUSTION AIR
DILUTION AIR
OXYGEN-ENRICHED AIR 1.3 HR (1 CONVERTER)
AIR 7.7 HR PER CONVERTER DAY (5 CONVERTERS)
FLUES & DUST COLLECTION

KEY
SOLIDS & LIQUIDS ———
GASES - - -
SCFM MEASURED AT 32°F AND ONE ATMOSPHERE
NIL – NEGLECTED (INSIGNIFICANT QUANTITY NOT AFFECTING MATERIAL BALANCE)
N.R. – NOT REPORTED (QUANTITY UNKNOWN)
* – ESTIMATED QUANTITY

BASIS
TONNAGES A
A 24-HOUR
TONS
S-SULFUR

A

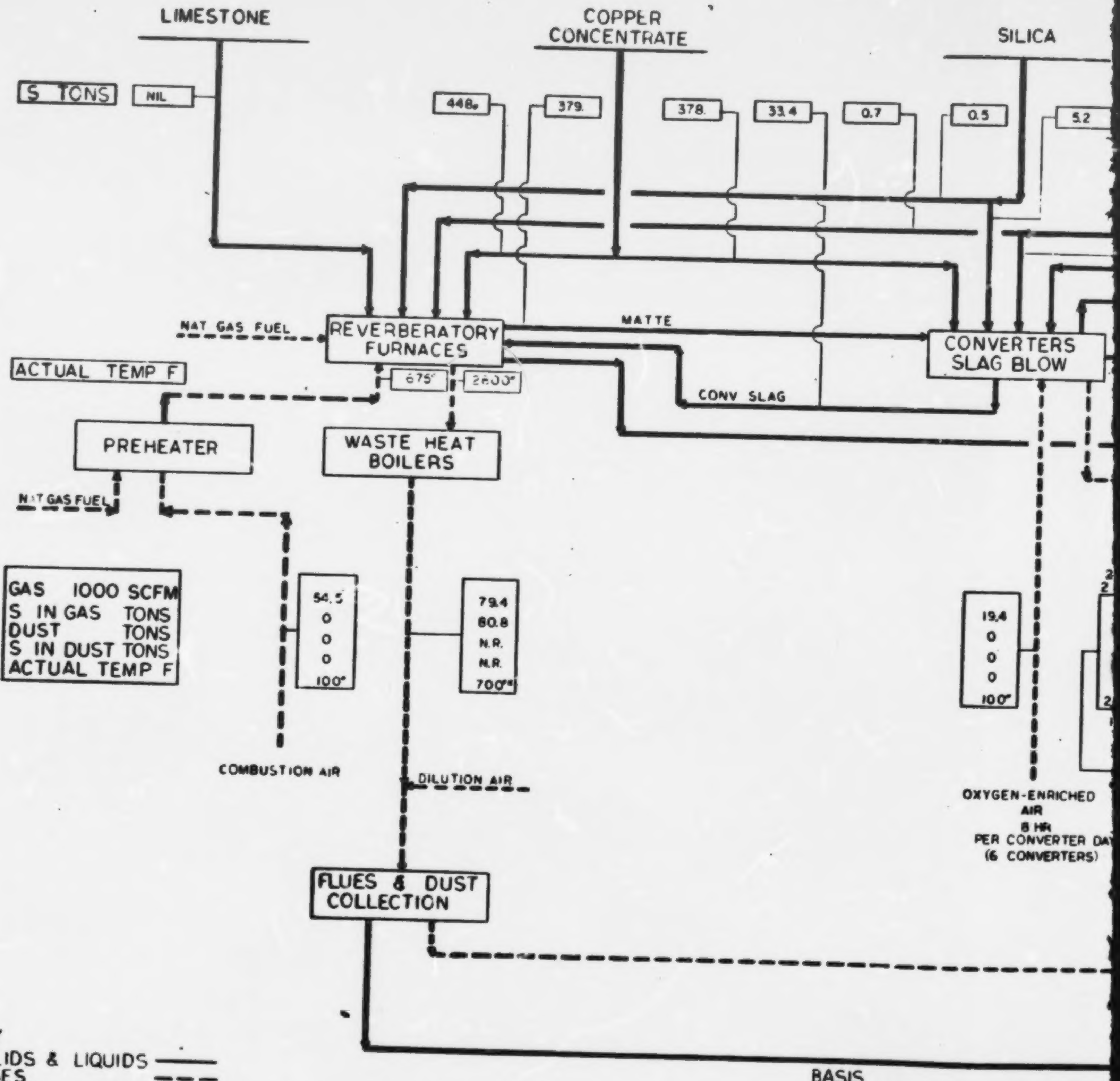

RECYCLE
SILICA
PRECIPITATE & RESIDUES
MISCELLANEOUS DUST & REVERTS
5.7
<0.1
214.
1.1*
9.8*
REVERTS
CONVERTERS SLAG BLOW
WHITE METAL
CONVERTERS FINISH BLOW
BLISTER TO REFINERY
S CONTENT 0.8 TONS
SLAG TO WASTE 1960 TONS
S CONTENT 19.6 TONS
TO ATMOSPHERE
TO ACID PLANT
21.5
0
0
0
100°
NRICHED
3 HR
ERTER)
2 SLAG 2 FINISH
66.1
349.
N.R.
N.R.
2250°
12 HR
2 SLAG 1 FINISH
53.6
273.
N.R.
N.R.
2250°
12 HR
12.6
0
0
0
100°
212.AV
346.
N.R.
N.R.
350°*
46.AV
158.
N.R.
N.R.
350°*
136.AV
464.
N.R.
N.R.
350°*
DILUTION AIR
AIR
7.7 HR
PER CONVERTER DAY
(5 CONVERTERS)
AIR
6 HR
PER CONVERTER DAY
(6 CONVERTERS)
CONVERTER GAS BYPASS
FLUES & DUST COLLECTION
TWO STACKS
REVERB GAS
CONVERTER GAS
DUST
TO DUST RECOVERY
S CONTENT 11 TONS

B

BASIS
TONNAGES ARE GIVEN FOR A 24-HOUR PERIOD IN SHORT TONS
S-SULFUR

NOTE
ALTHOUGH SHOWN AS SEPARATE BLOCKS THE SAME CONVERTER IS USED FOR SLAG AND FINISH BLOWS

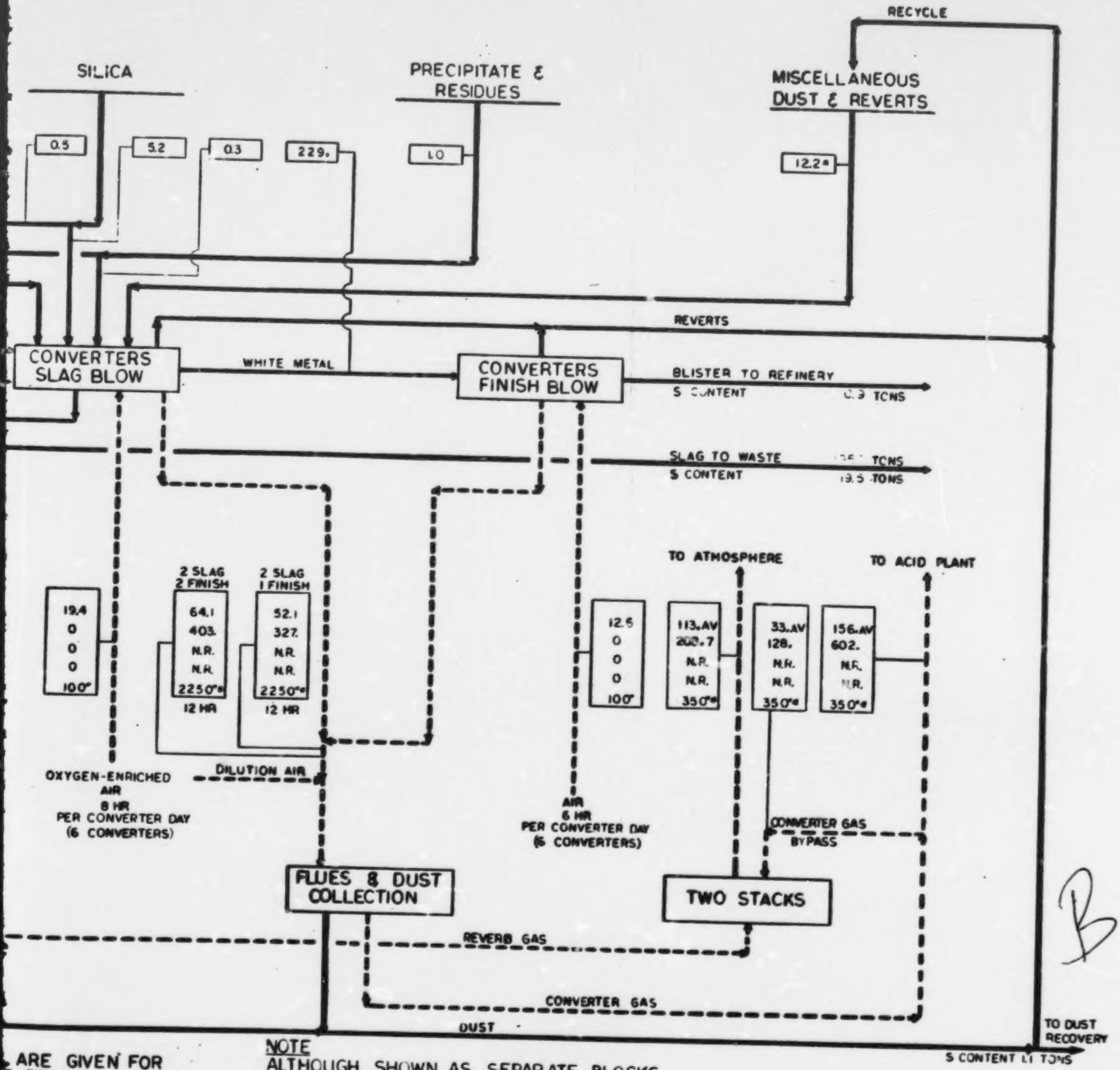
CLIENT NATIONAL AIR POLLUTION CONTROL ADMINISTRATION	ARTHUR G. MCKEE & COMPANY WESTERN KNAPP ENGINEERING DIVISION SAN FRANCISCO CALIFORNIA
TITLE 326.35 COPPER PLANT 1968 FLOW DIAGRAM	ENG DEPT DWG 10-01-044 PLATE NO. A-16


LIMESTONE
COPPER CONCENTRATE
SILICA
S TONS
NIL
448.
379.
378.
33.4
0.7
0.5
5.2
NAT GAS FUEL
REVERBERATORY FURNACES
MATTE
CONVERTERS SLAG BLOW
ACTUAL TEMP F
675°
2800°
CONV SLAG
PREHEATER
WASTE HEAT BOILERS
NAT GAS FUEL
GAS 1000 SCFM
S IN GAS TONS
DUST TONS
S IN DUST TONS
ACTUAL TEMP F
54.5
0
0
0
100°
79.4
80.8
N.R.
N.R.
700°*
19.4
0
0
0
100°
COMBUSTION AIR
DILUTION AIR
OXYGEN-ENRICHED AIR
8 HR PER CONVERTER DAY
(6 CONVERTERS)
FLUES & DUST COLLECTION

KEY
SOLIDS & LIQUIDS ———
GASES - - -
SCFM MEASURED AT 32°F AND ONE ATMOSPHERE
NIL - NEGLECTED (INSIGNIFICANT QUANTITY NOT AFFECTING MATERIAL BALANCE)
N.R. - NOT REPORTED (QUANTITY UNKNOWN)
* ESTIMATED QUANTITY

BASIS
TONNAGES ARE GIVEN FOR A 24-HOUR PERIOD IN SHORT TONS
S-SULFUR

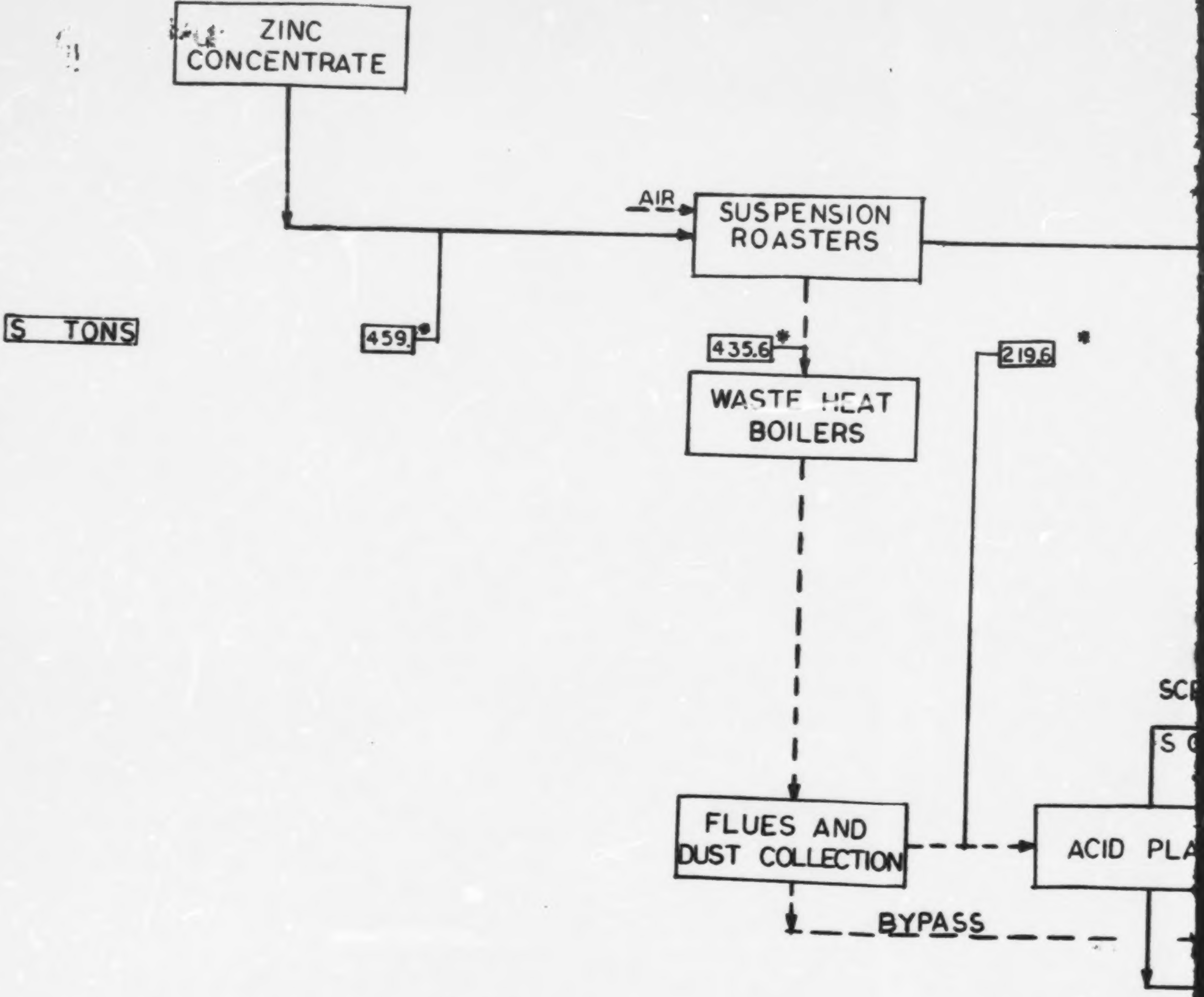
A


RECYCLE
SILICA
PRECIPITATE & RESIDUES
MISCELLANEOUS DUST & REVERTS
0.5
5.2
0.3
229.
1.0
12.2ᵃ
REVERTS
CONVERTERS SLAG BLOW
WHITE METAL
CONVERTERS FINISH BLOW
BLISTER TO REFINERY
S CONTENT 0.3 TONS
SLAG TO WASTE [illegible] TONS
S CONTENT 19.5 TONS
TO ATMOSPHERE
TO ACID PLANT
19.4
0
0
0
100°
2 SLAG 2 FINISH
64.1
403.
N.R.
N.R.
2250°ᵉ
12 HR
2 SLAG 1 FINISH
52.1
327.
N.R.
N.R.
2250°ᵉ
12 HR
12.5
0
0
0
100°
113.AV
200.7
N.R.
N.R.
350°ᵉ
33.AV
128.
N.R.
N.R.
350°ᵉ
156.AV
602.
N.R.
N.R.
350°ᵉ
OXYGEN-ENRICHED AIR
8 HR
PER CONVERTER DAY
(6 CONVERTERS)
DILUTION AIR
AIR
6 HR
PER CONVERTER DAY
(6 CONVERTERS)
CONVERTER GAS BYPASS
FLUES & DUST COLLECTION
TWO STACKS
REVERB GAS
CONVERTER GAS
DUST
TO DUST RECOVERY
S CONTENT 1.1 TONS
B

ARE GIVEN FOR
R PERIOD IN SHORT

NOTE
ALTHOUGH SHOWN AS SEPARATE BLOCKS
THE SAME CONVERTER IS USED FOR
SLAG AND FINISH BLOWS

NATIONAL AIR POLLUTION CONTROL ADMINISTRATION	ARTHUR G. McKEE & COMPANY WESTERN KNAPP ENGINEERING DIVISION SAN FRANCISCO CALIFORNIA
326.35 COPPER PLANT 1970 FLOW DIAGRAM	ENG. DEPT. DWG. 10-01-045 PLATE NO. A-17

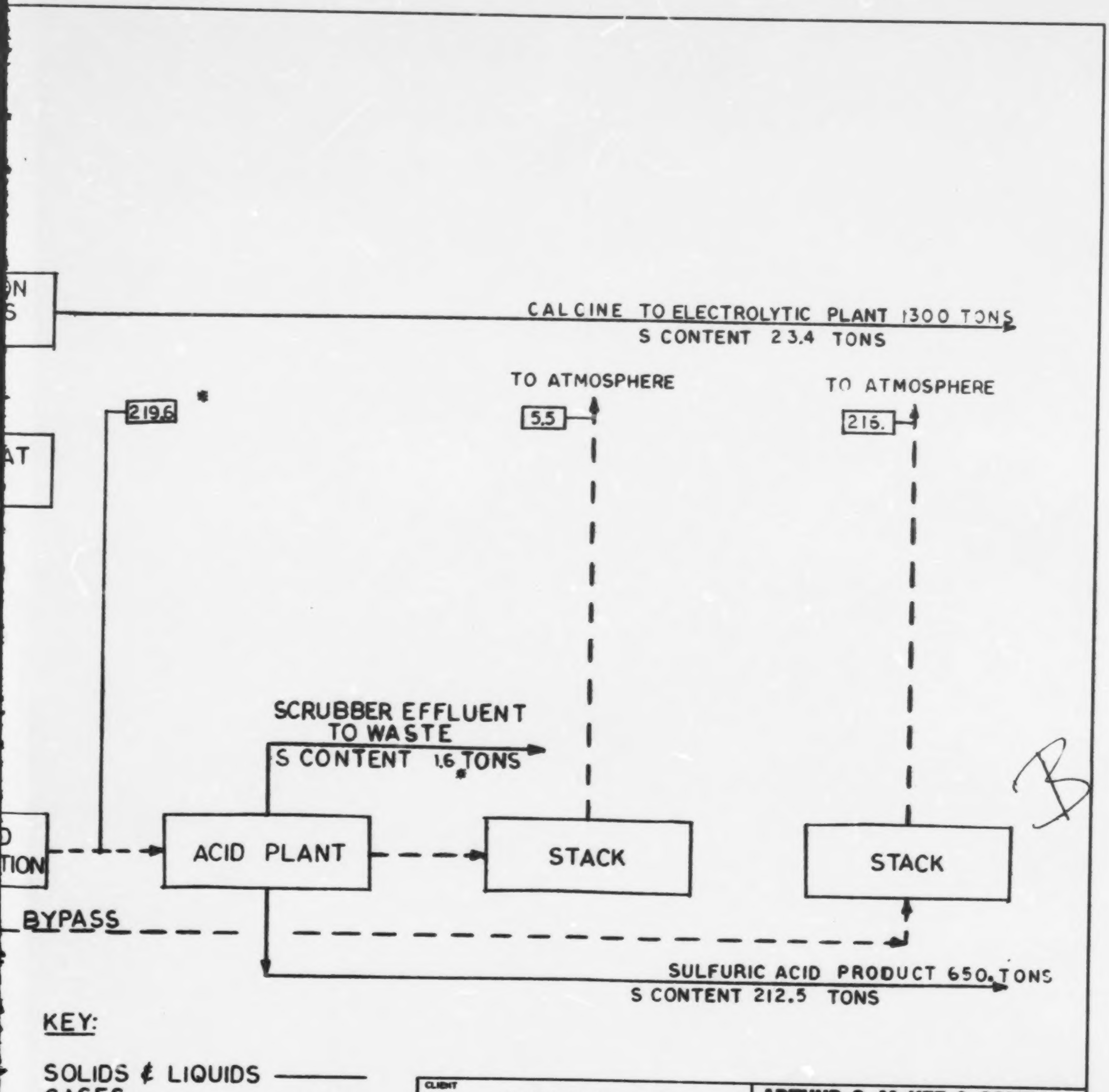

ZINC CONCENTRATE
AIR
SUSPENSION ROASTERS
S TONS
459*
435.6*
WASTE HEAT BOILERS
219.6 *
SC
S G
FLUES AND DUST COLLECTION
ACID PLA
BYPASS

BASIS:
TONNAGES ARE GIVEN FOR A 24-HOUR PERIOD IN SHORT TONS

S-SULFUR

KEY:

SOLIDS & LIQUIDS —
GASES —
*ESTIMATED QUANTIT


ON
S
CALCINE TO ELECTROLYTIC PLANT 1300 TONS
S CONTENT 23.4 TONS
TO ATMOSPHERE
TO ATMOSPHERE
219.6 *
5.5
216.
AT
SCRUBBER EFFLUENT
TO WASTE
S CONTENT 1.6 TONS *
B
D
TION
ACID PLANT
STACK
STACK
BYPASS
SULFURIC ACID PRODUCT 650. TONS
S CONTENT 212.5 TONS
KEY:
SOLIDS & LIQUIDS
GASES
*ESTIMATED QUANTITY

CLIENT

NATIONAL AIR
POLLUTION CONTROL
ADMINISTRATION

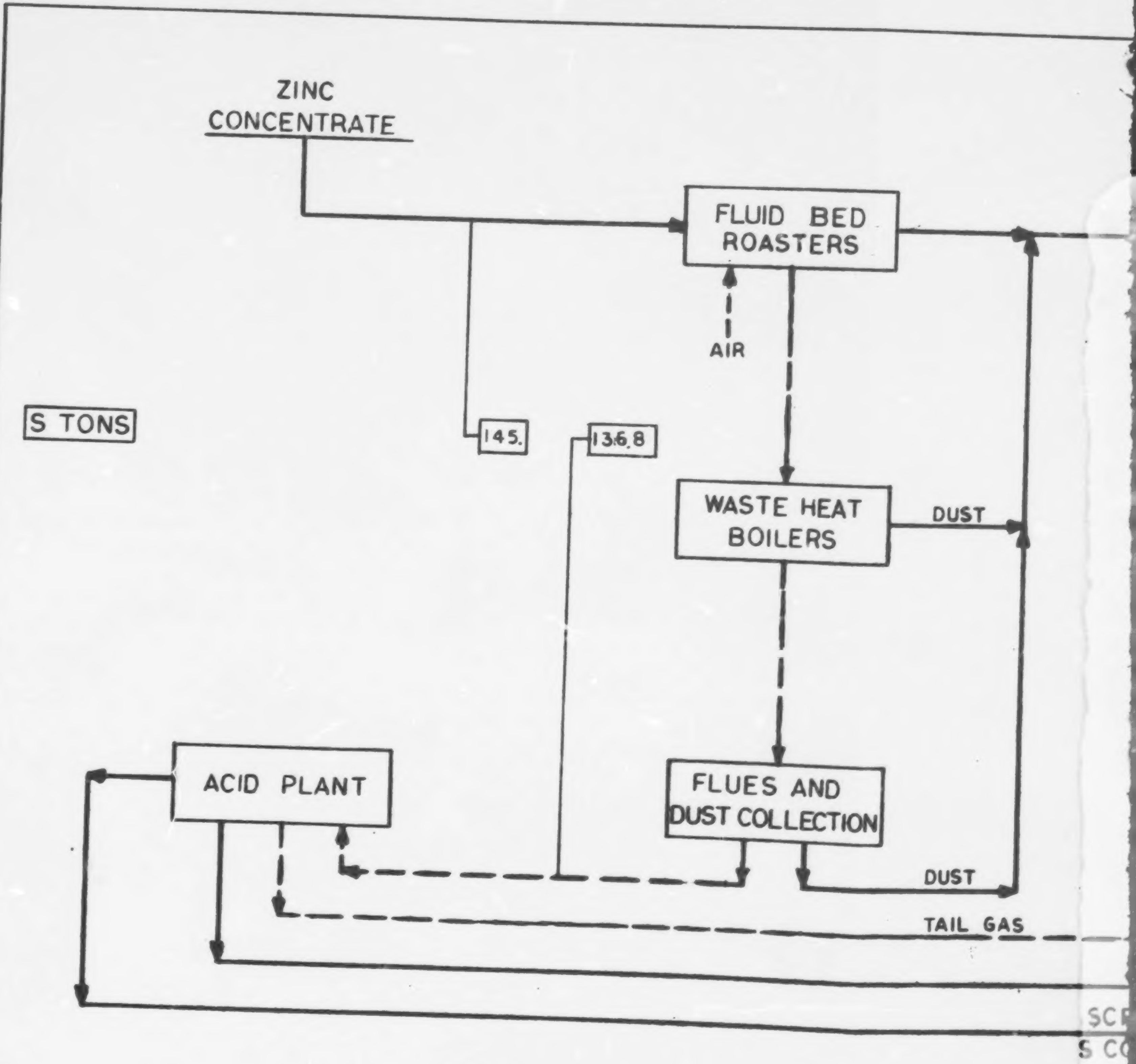
ARTHUR G. McKEE & COMPANY
WESTERN KNAPP ENGINEERING DIVISION
SAN FRANCISCO CALIFORNIA

TITLE

326.10
ZINC PLANT
FLOW DIAGRAM

ENG. DEPT. DWG. 10-01-014

PLATE NO. A-18

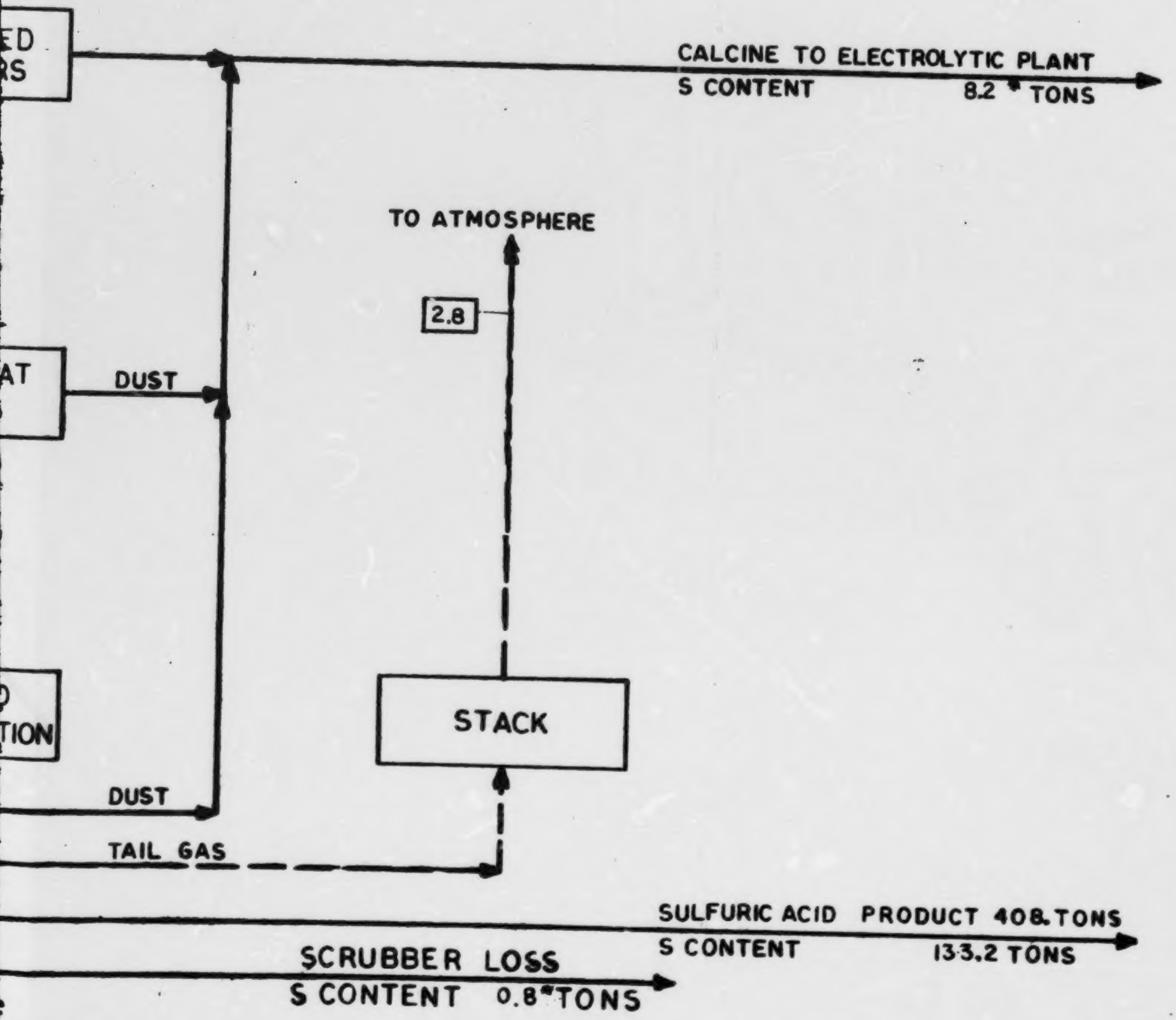

ZINC CONCENTRATE
FLUID BED ROASTERS
AIR
S TONS
145.
136.8
WASTE HEAT BOILERS
DUST
ACID PLANT
FLUES AND DUST COLLECTION
DUST
TAIL GAS
SCF
S CO

BASIS:
TONNAGES ARE GIVEN
FOR A 24-HOUR PERIOD
IN SHORT TONS

S-SULFUR

KEY:

SOLIDS & LIQUIDS
GASES
SCFM MEASURED AT
AND ONE ATMOSPHE
* ESTIMATED QUAN


ED
RS
CALCINE TO ELECTROLYTIC PLANT
S CONTENT 8.2 * TONS
TO ATMOSPHERE
2.8
AT
DUST
D
TION
STACK
DUST
TAIL GAS
SULFURIC ACID PRODUCT 408 TONS
S CONTENT 133.2 TONS
SCRUBBER LOSS
S CONTENT 0.8* TONS

B

KEY:

SOLIDS & LIQUIDS ———
GASES — — —
SCFM MEASURED AT 32° F
AND ONE ATMOSPHERE
*ESTIMATED QUANTITY

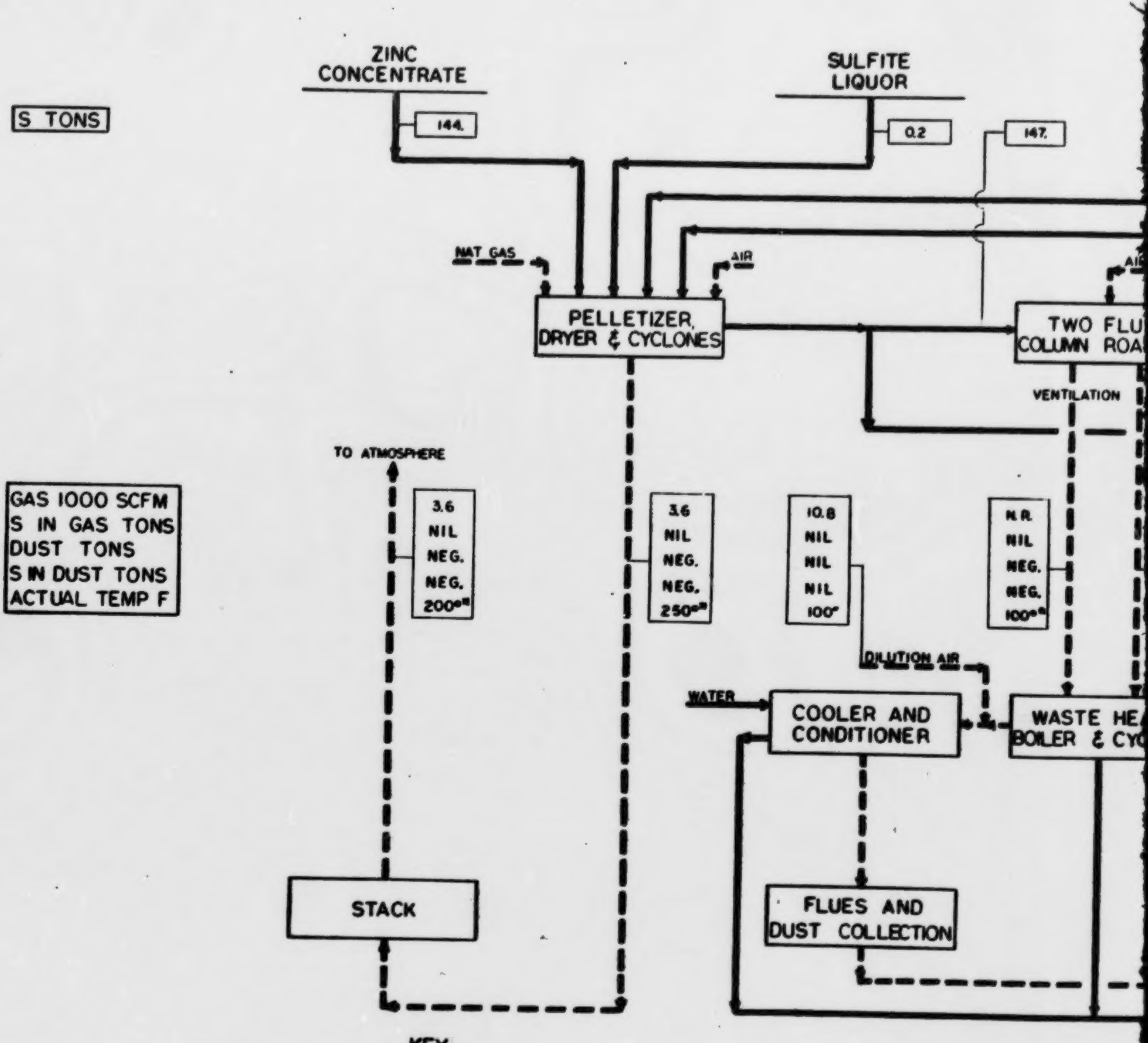
CLIENT
NATIONAL AIR
POLLUTION CONTROL
ADMINISTRATION

TITLE
326.12
ZINC PLANT
FLOW DIAGRAM

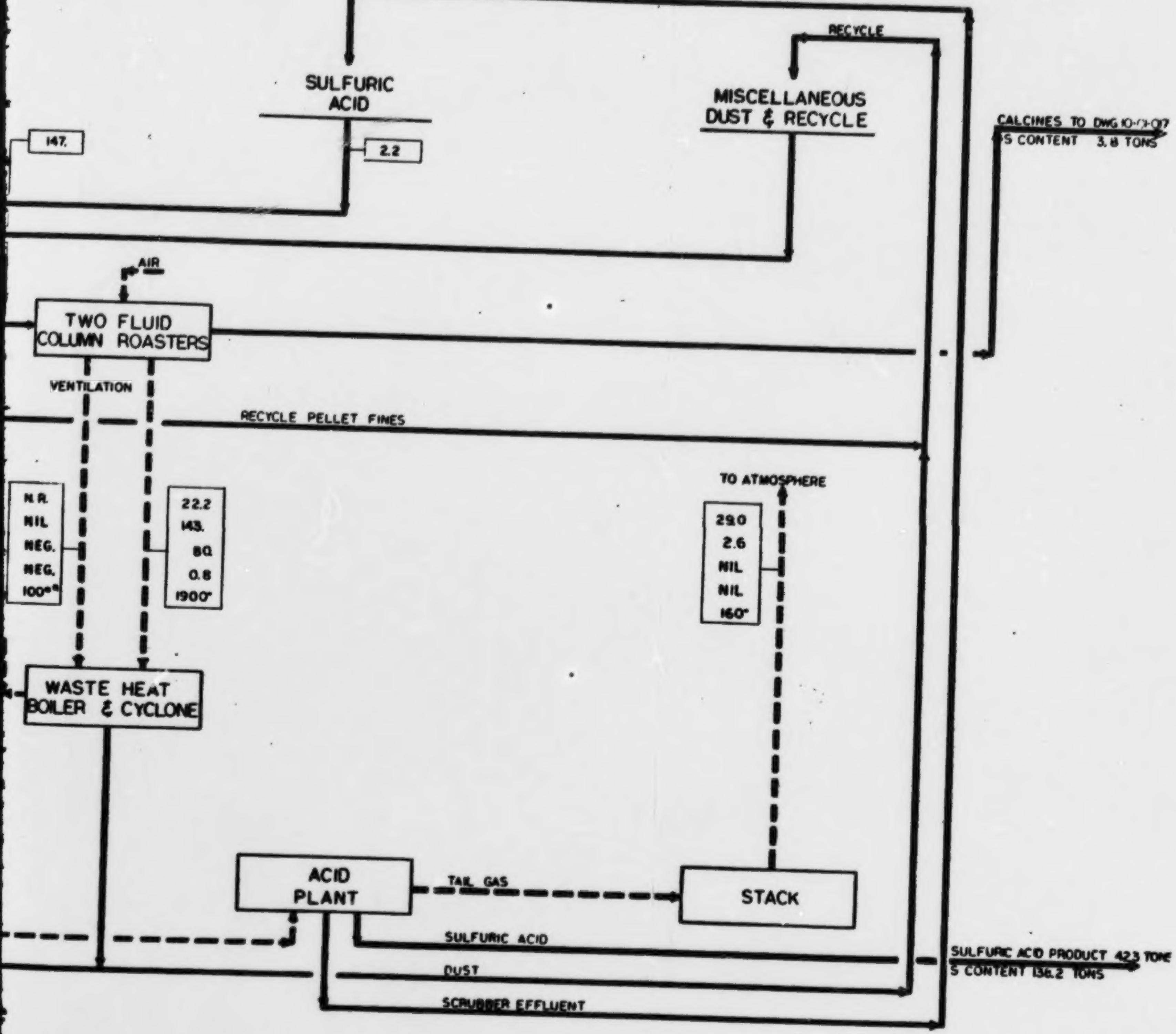
ARTHUR G. McKEE & COMPANY
WESTERN KNAPP ENGINEERING DIVISION
SAN FRANCISCO CALIFORNIA

ENG. DEPT. DWG. 10-01-0

PLATE NO. A-19


S TONS
ZINC CONCENTRATE
144.
SULFITE LIQUOR
0.2
147.
NAT GAS
AIR
AIR
PELLETIZER, DRYER & CYCLONES
TWO FLU
COLUMN ROA
VENTILATION
TO ATMOSPHERE
GAS 1000 SCFM
S IN GAS TONS
DUST TONS
S IN DUST TONS
ACTUAL TEMP F
3.6
NIL
NEG.
NEG.
200°*
3.6
NIL
NEG.
NEG.
250°*
10.8
NIL
NIL
NIL
100°
N.R.
NIL
NEG.
NEG.
100°*
DILUTION AIR
WATER
COOLER AND CONDITIONER
WASTE HEA
BOILER & CY
STACK
FLUES AND DUST COLLECTION

KEY:
SOLIDS & LIQUIDS ———
GASES — — —
SCFM MEASURED AT 32°F & ONE ATMOSPHERE
NIL - NEGLECTED(INSIGNIFICANT QUANTITY NOT AFFECTING MATERIAL BALA
NEG. - NEGLECTED(MINOR QUANTITY PRESENT, BUT NOT REPORTED OR EST
N.R. - NOT REPORTED(QUANTITY UNKNOWN)
* - ESTIMATED QUANTITY


SULFURIC
ACID
147.
2.2
RECYCLE
MISCELLANEOUS
DUST & RECYCLE
CALCINES TO DWG 10-()-017
S CONTENT 3.8 TONS
AIR
TWO FLUID
COLUMN ROASTERS
VENTILATION
RECYCLE PELLET FINES
N.R.
NIL
NEG.
NEG.
100°
22.2
143.
8.0
0.8
1900°
TO ATMOSPHERE
29.0
2.6
NIL
NIL
160°
WASTE HEAT
BOILER & CYCLONE
ACID
PLANT
TAIL GAS
STACK
SULFURIC ACID
DUST
SCRUBBER EFFLUENT
SULFURIC ACID PRODUCT 423 TONS
S CONTENT 136.2 TONS

MATERIAL BALANCE)
ORTED OR ESTIMATED)

BASIS:
TONNAGES ARE GIVEN
FOR A 24-HOUR PERIOD
IN SHORT TONS

S-SULFUR

B

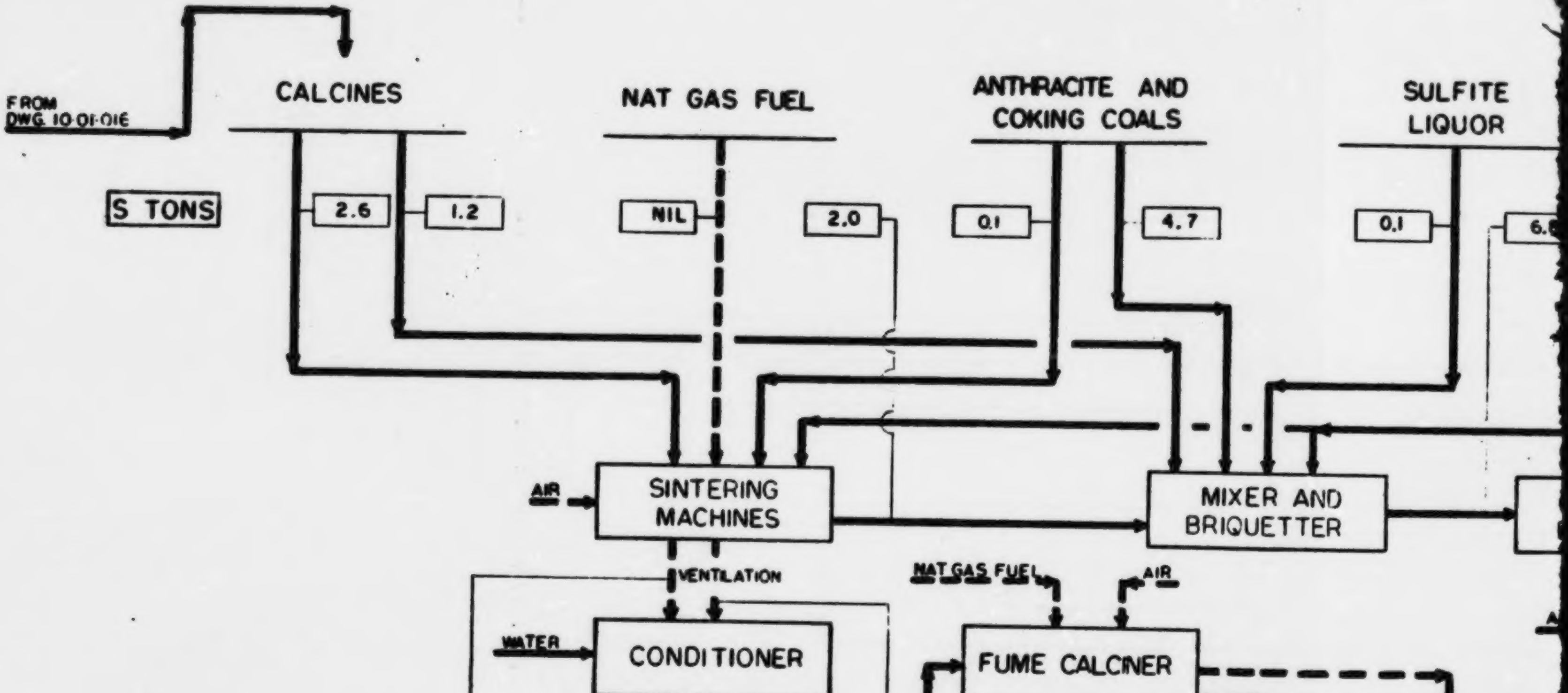
NATIONAL AIR
POLLUTION CONTROL
ADMINISTRATION

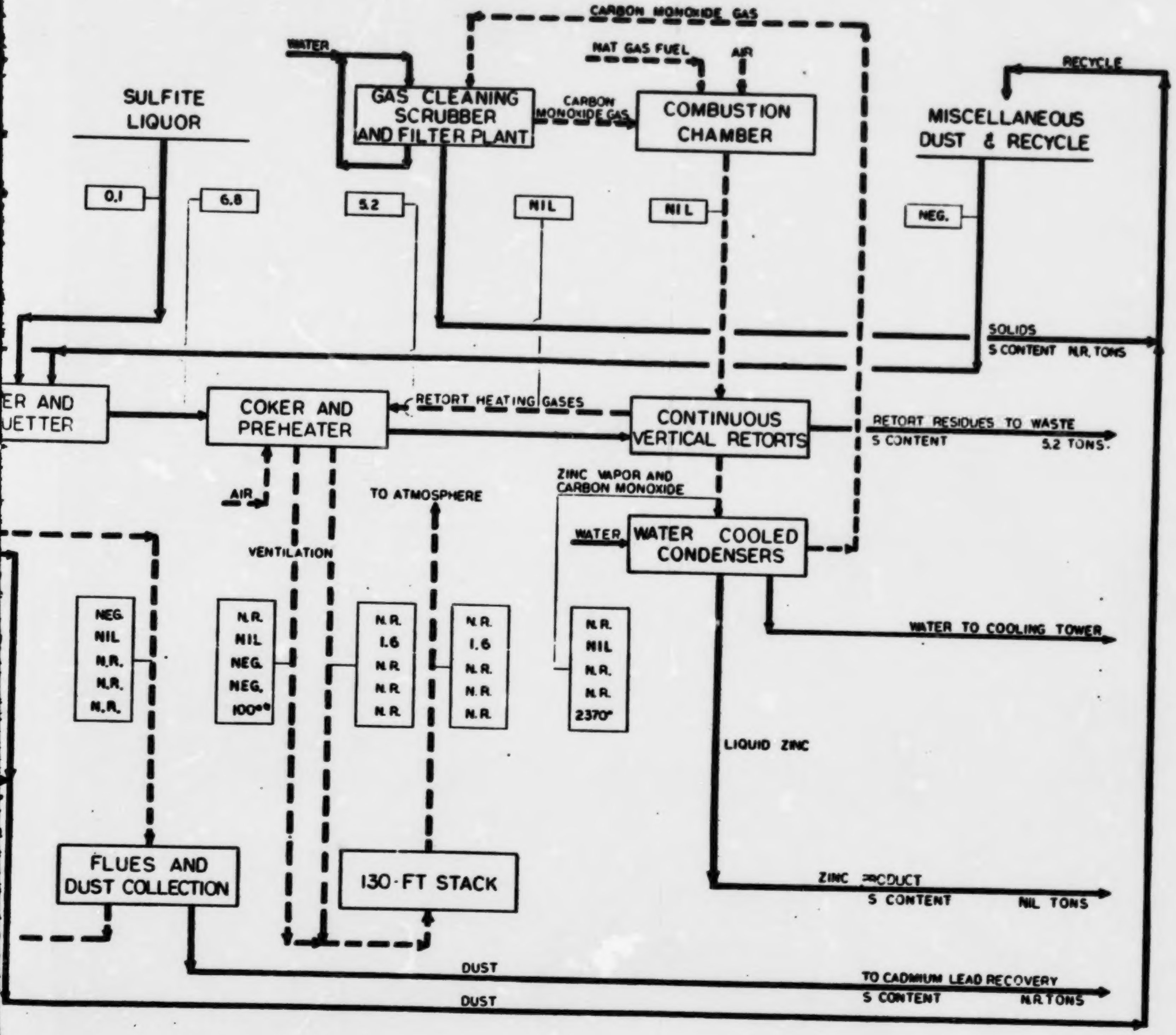
326.14
ZINC PLANT
FLOW DIAGRAM

ARTHUR G. McKEE & COMPANY
WESTERN KNAPP ENGINEERING DIVISION
SAN FRANCISCO CALIFORNIA

ENG. DEPT. DWG. 10-01-016

PLATE NO. A-20


FROM DWG. 10-01-016
CALCINES
NAT GAS FUEL
ANTHRACITE AND COKING COALS
SULFITE LIQUOR
S TONS
2.6
1.2
NIL
2.0
0.1
4.7
0.1
6.6
AIR
SINTERING MACHINES
MIXER AND BRIQUETTER
VENTILATION
NAT GAS FUEL
AIR
WATER
CONDITIONER
FUME CALCINER
DILUTION AIR
TO ATMOSPHERE
GAS 1000 SCFM
S IN GAS TONS
DUST TONS
S IN DUST TONS
ACTUAL TEMP F
23.2
0.7
N.R.
N.R.
400°
N.R.
NIL
NEG.
NEG.
100°*
23.2
0.7
N.R.
N.R.
130°*
NEG.
NIL
N.R.
N.R.
N.R.
DUST
FLUES AND DUST COLLECTION
DUST
100-FT STACK
FLUES AND DUST COLLECTION
KEY
SOLIDS & LIQUIDS
GASES
SCFM MEASURED AT 32°F AND ONE ATMOSPHERE
NIL - NEGLECTED(INSIGNIFICANT QUANTITY NOT AFFECTING MATERIAL BAL
NEG.- NEGLECTED(MINOR QUANTITY PRESENT, BUT NOT REPORTED OR E
N.R.- NOT REPORTED(QUANTITY UNKNOWN)
* - ESTIMATED QUANTITY


CARBON MONOXIDE GAS
WATER
NAT GAS FUEL
AIR
RECYCLE
SULFITE LIQUOR
GAS CLEANING SCRUBBER AND FILTER PLANT
CARBON MONOXIDE GAS
COMBUSTION CHAMBER
MISCELLANEOUS DUST & RECYCLE
0.1
6.8
5.2
NIL
NIL
NEG.
SOLIDS
S CONTENT N.R. TONS
ER AND
UETTER
COKER AND PREHEATER
RETORT HEATING GASES
CONTINUOUS VERTICAL RETORTS
RETORT RESIDUES TO WASTE
S CONTENT 5.2 TONS
ZINC VAPOR AND CARBON MONOXIDE
AIR
TO ATMOSPHERE
WATER
WATER COOLED CONDENSERS
VENTILATION
WATER TO COOLING TOWER
NEG.
NIL
N.R.
N.R.
N.R.
N.R.
NIL
NEG.
NEG.
100°*
N.R.
1.6
N.R.
N.R.
N.R.
N.R.
1.6
N.R.
N.R.
N.R.
N.R.
NIL
N.R.
N.R.
2370°
LIQUID ZINC
FLUES AND DUST COLLECTION
130-FT STACK
ZINC PRODUCT
S CONTENT NIL TONS
DUST
TO CADMIUM LEAD RECOVERY
DUST
S CONTENT N.R. TONS

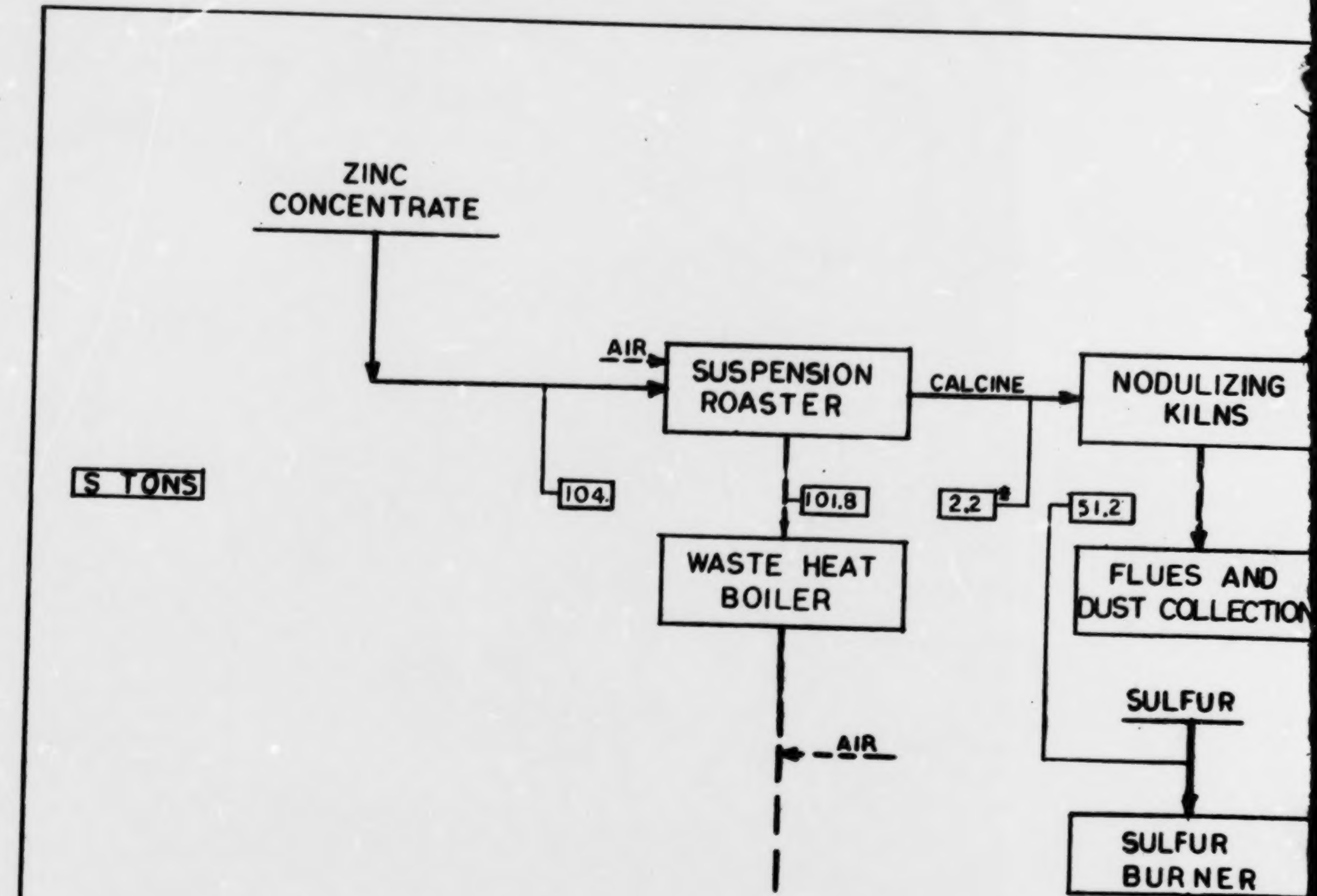
RE
FFECTING MATERIAL BALANCE)
NOT REPORTED OR ESTIMATED)

BASIS:
TONNAGES ARE GIVEN
FOR A 24-HOUR PERIOD
IN SHORT TONS

S-SULFUR

B

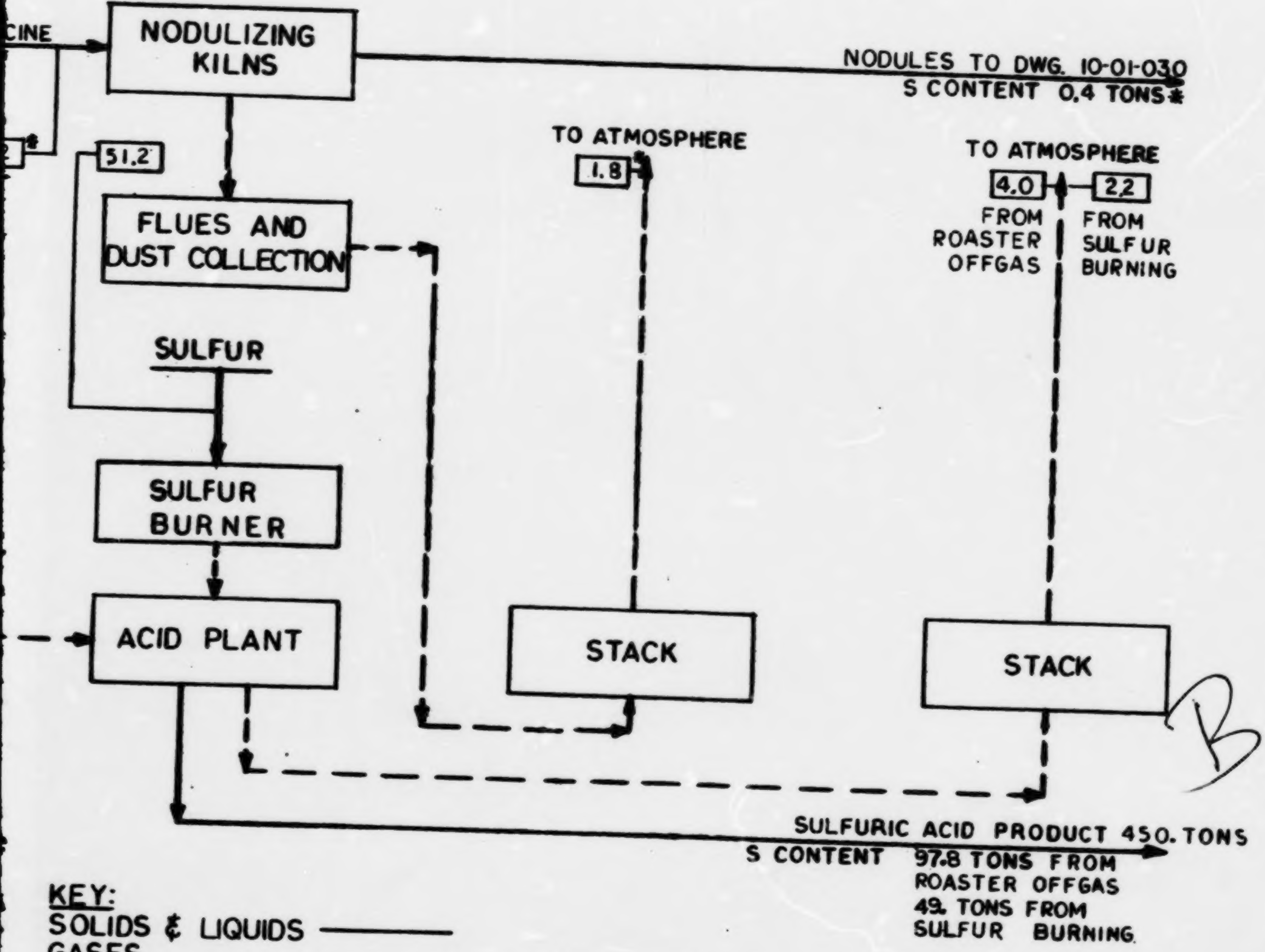
CLIENT	
NATIONAL AIR POLLUTION CONTROL ADMINISTRATION	ARTHUR G. McKEE & COMPANY WESTERN KNAPP ENGINEERING DIVISION SAN FRANCISCO CALIFORNIA
TITLE 326.14 ZINC PLANT FLOW DIAGRAM	ENG. DEPT. DWG. 10-01-017 **PLATE NO. A-21**


ZINC CONCENTRATE
AIR
SUSPENSION ROASTER
CALCINE
NODULIZING KILNS
S TONS
104.
101.8
2.2*
51.2
WASTE HEAT BOILER
FLUES AND DUST COLLECTION
SULFUR
AIR
SULFUR BURNER
FLUES AND DUST COLLECTION
ACID PLANT

BASIS:
TONNAGES ARE GIVEN
FOR A 24-HOUR PERIOD
IN SHORT TONS

S-SULFUR

KEY:
SOLIDS & LIQUIDS —
GASES
*ESTIMATED QUANT


CINE
NODULIZING KILNS
NODULES TO DWG. 10-01-030
S CONTENT 0.4 TONS*
2*
51.2
FLUES AND DUST COLLECTION
TO ATMOSPHERE
1.8
TO ATMOSPHERE
4.0
FROM ROASTER OFFGAS
2.2
FROM SULFUR BURNING
SULFUR
SULFUR BURNER
ACID PLANT
STACK
STACK
B
SULFURIC ACID PRODUCT 450. TONS
S CONTENT 97.8 TONS FROM ROASTER OFFGAS
49. TONS FROM SULFUR BURNING

KEY:
SOLIDS & LIQUIDS ————
GASES — — —
*ESTIMATED QUANTITY

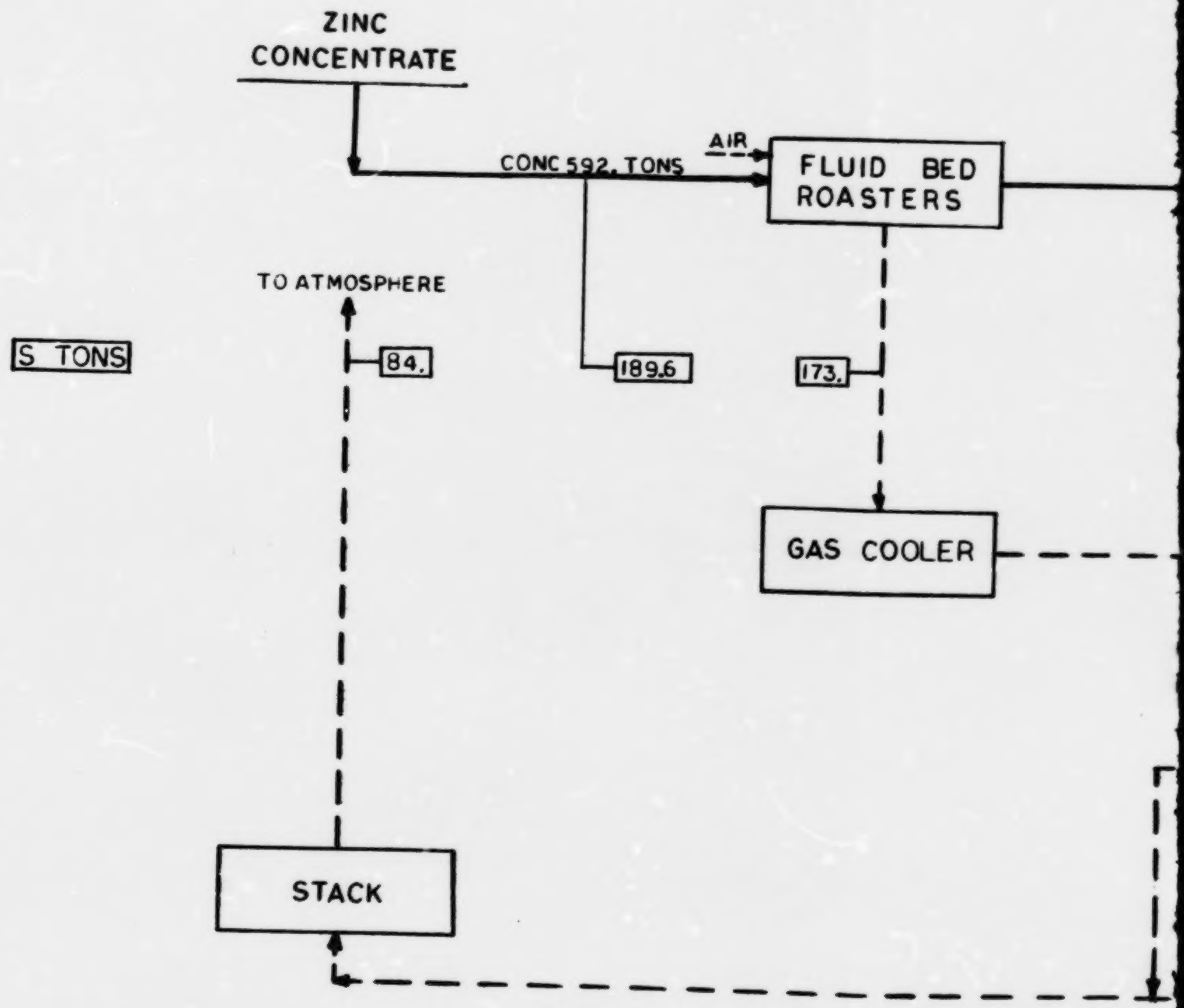
CLIENT
NATIONAL AIR
POLLUTION CONTROL
ADMINISTRATION

TITLE
326.15
ZINC PLANT
FLOW DIAGRAM

ARTHUR G. McKEE & COMPANY
WESTERN KNAPP ENGINEERING DIVISION
SAN FRANCISCO CALIFORNIA

ENG. DEPT. DWG. 10-01-0[illegible]

PLATE NO. A-22

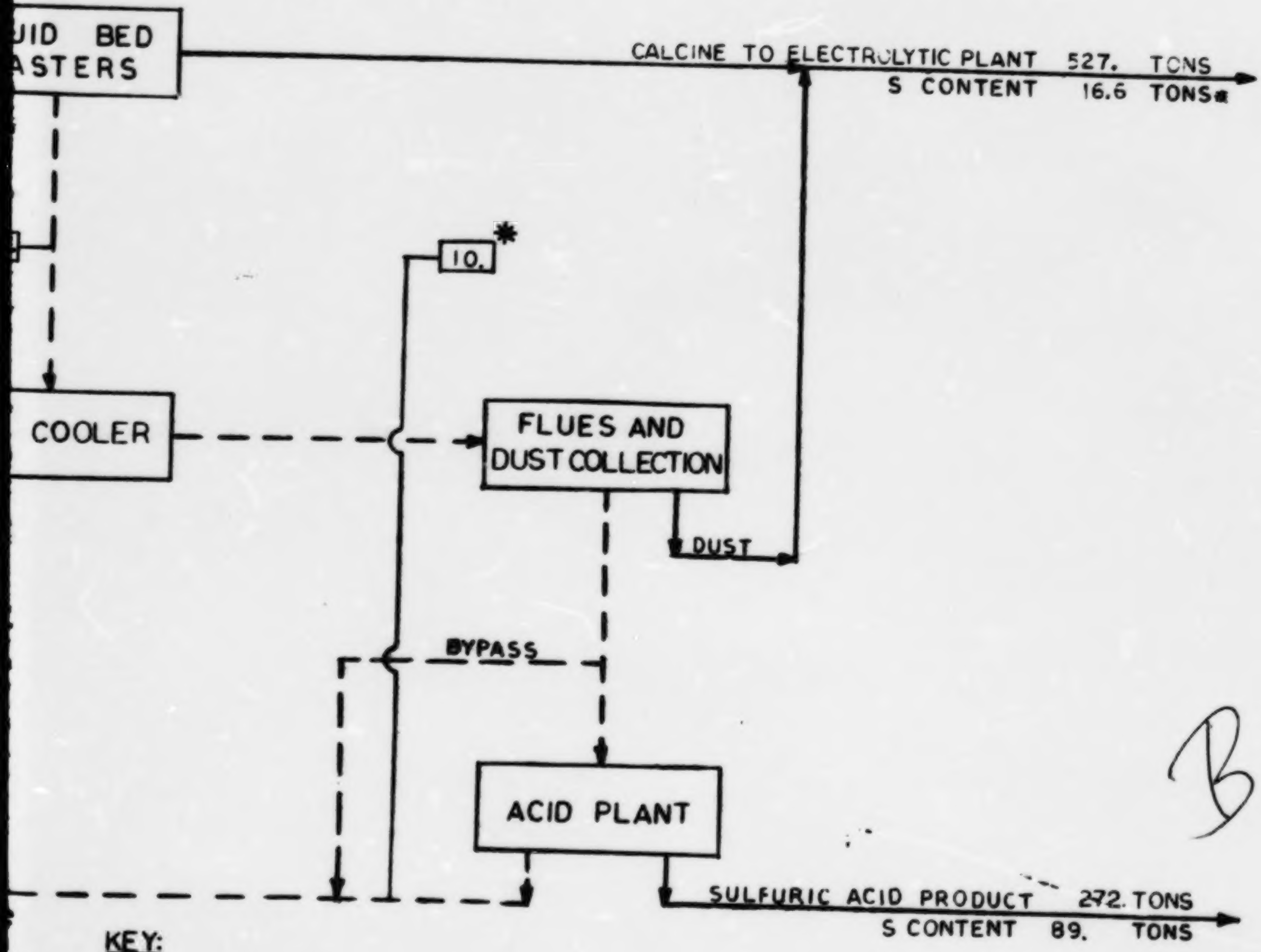

ZINC CONCENTRATE
AIR
CONC 592. TONS
FLUID BED ROASTERS
TO ATMOSPHERE
S TONS
84.
189.6
173.
GAS COOLER
STACK

BASIS:
TONNAGES ARE GIVEN
FOR A 24-HOUR PERIOD
IN SHORT TONS

S-SULFUR

KEY:

SOLIDS & LIQUIDS
GASES
SCFM MEASURED
AND ONE ATMOSP
*ESTIMATED QUA


UID BED
ASTERS
CALCINE TO ELECTROLYTIC PLANT 527. TONS
S CONTENT 16.6 TONS#
10.*
COOLER
FLUES AND
DUST COLLECTION
DUST
BYPASS
ACID PLANT
SULFURIC ACID PRODUCT 272. TONS
S CONTENT 89. TONS

B

KEY:

SOLIDS & LIQUIDS ————
GASES – – –
SCFM MEASURED AT 32° F
AND ONE ATMOSPHERE
#ESTIMATED QUANTITY

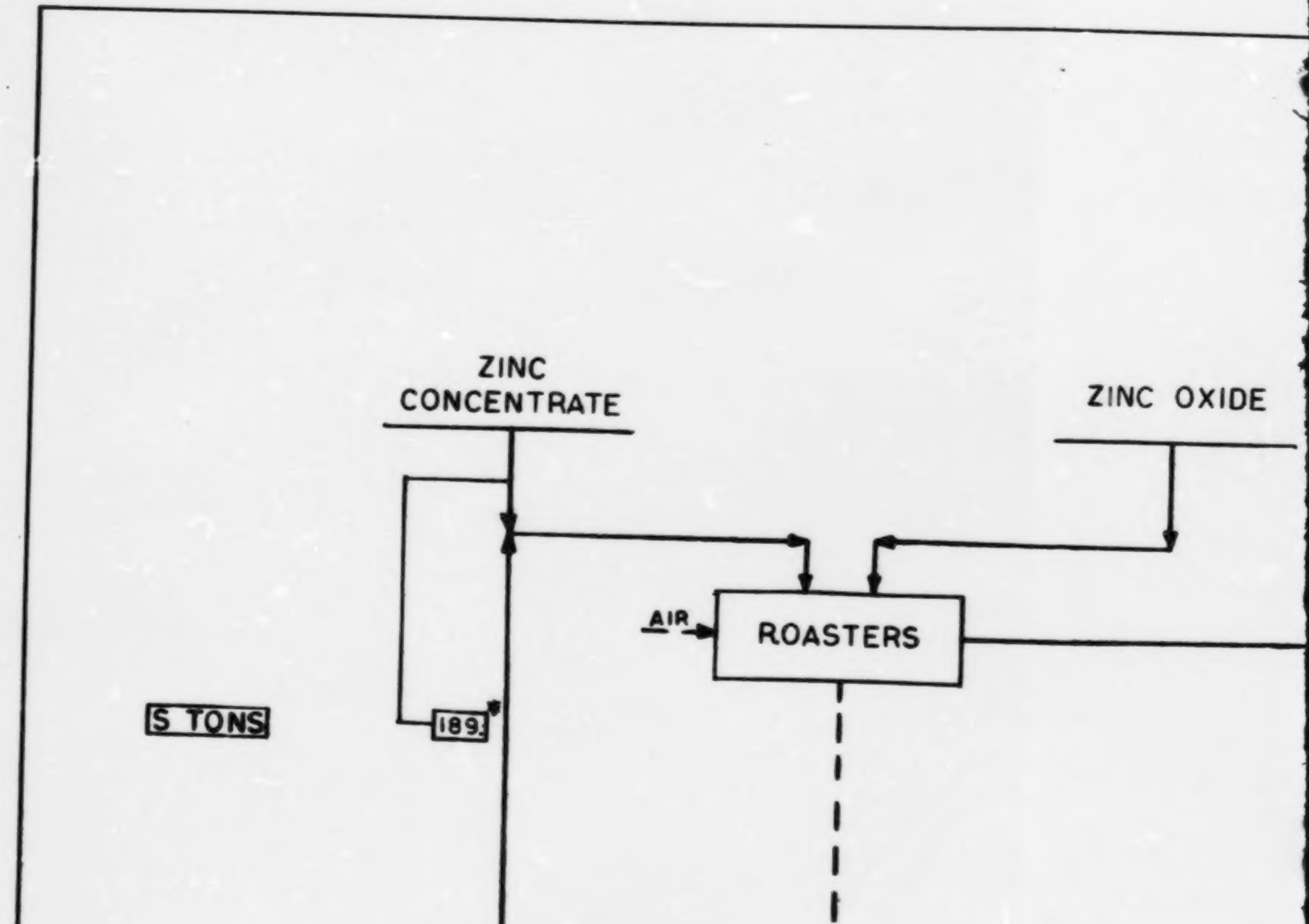
CLIENT
NATIONAL AIR
POLLUTION CONTROL
ADMINISTRATION

TITLE
326.20
ZINC PLANT
FLOW DIAGRAM

ARTHUR G. McKEE & COMPANY
WESTERN KNAPP ENGINEERING DIVISION
SAN FRANCISCO CALIFORNIA

ENG. DEPT. DWG. 10-01-05

PLATE NO. A-23

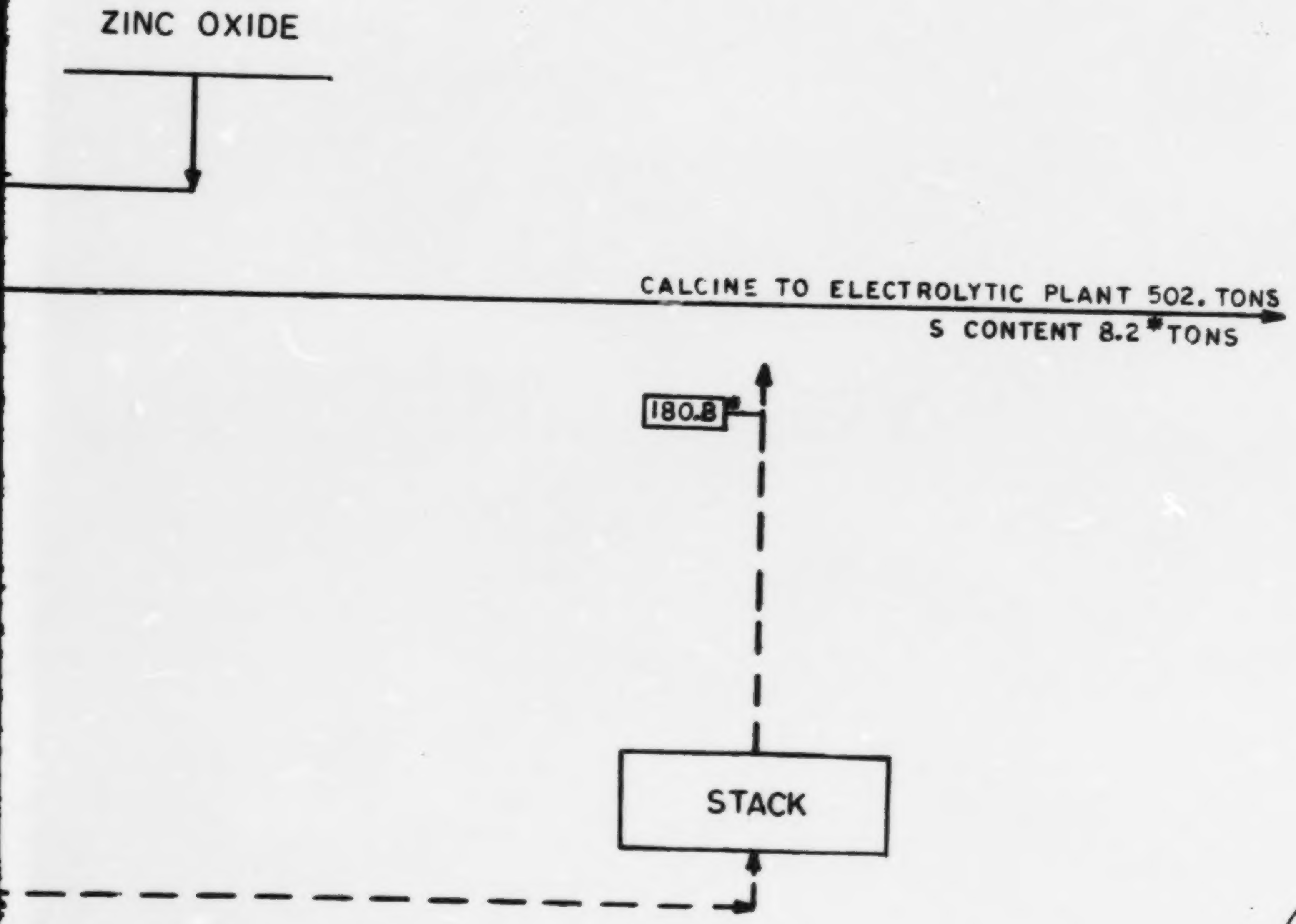

ZINC CONCENTRATE
ZINC OXIDE
AIR
ROASTERS
S TONS
189.*
FLUES AND DUST COLLECTION

BASIS:
TONNAGES ARE GIVEN
FOR A 24 HOUR PERIOD
IN SHORT TONS

S-SULFUR

KEY:

SOLIDS & LIQUIDS
GASES
*ESTIMATED QUANTI


ZINC OXIDE
CALCINE TO ELECTROLYTIC PLANT 502. TONS
S CONTENT 8.2* TONS
180.8*
STACK

B

EY:

OLIDS & LIQUIDS ————
ASES – – – –
ESTIMATED QUANTITY

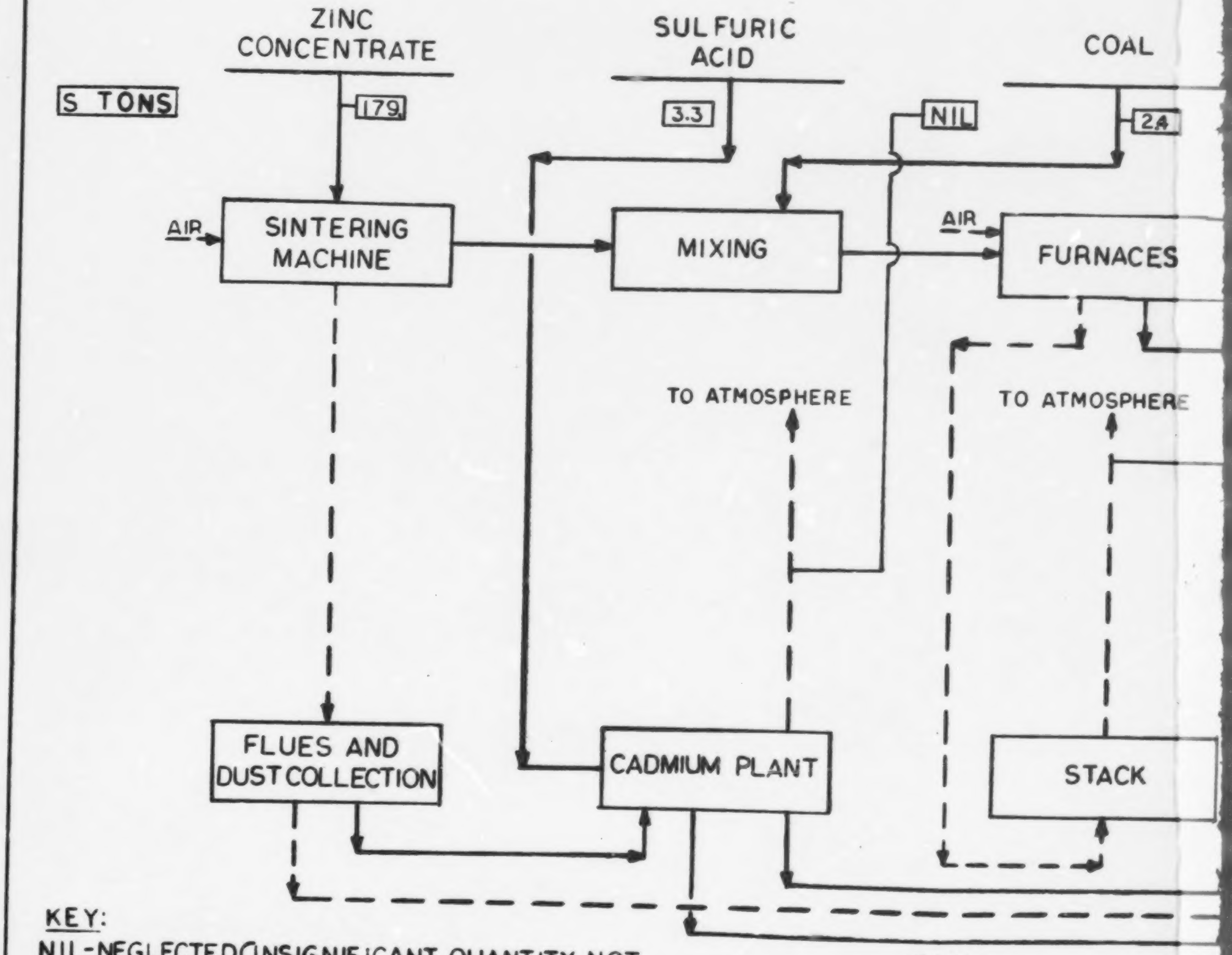
CLIENT
NATIONAL AIR
POLLUTION CONTROL
ADMINISTRATION

TITLE
326.21
ZINC PLANT
FLOW DIAGRAM

ARTHUR G. McKEE & COMPANY
WESTERN KNAPP ENGINEERING DIVISION
SAN FRANCISCO CALIFORNIA

ENG. DEPT. DWG. 10-01-0[illegible]

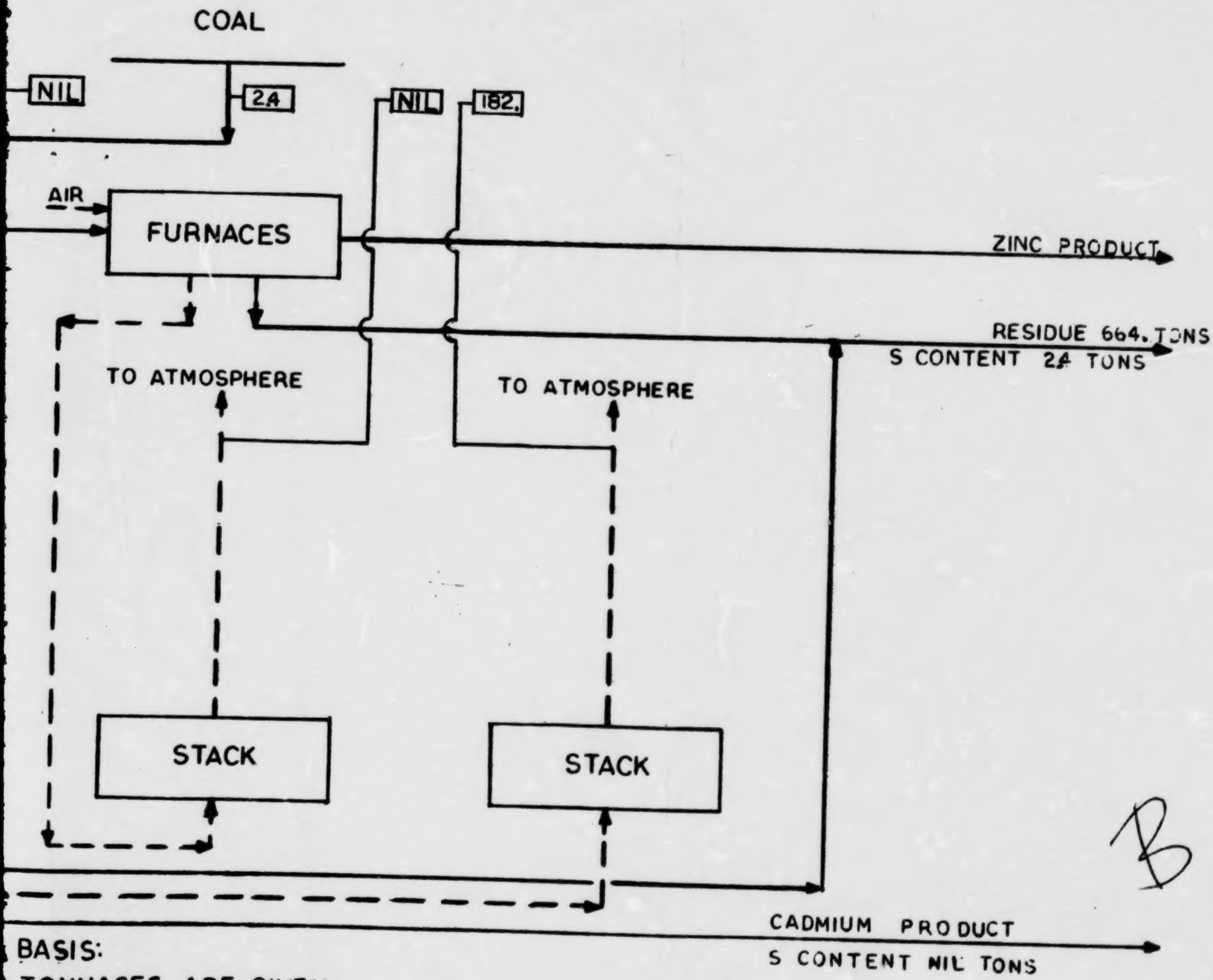
PLATE NO. A-24


ZINC CONCENTRATE
SULFURIC ACID
COAL
S TONS
179
3.3
NIL
2.4
AIR
SINTERING MACHINE
MIXING
AIR
FURNACES
TO ATMOSPHERE
TO ATMOSPHERE
FLUES AND DUST COLLECTION
CADMIUM PLANT
STACK

KEY:
NIL-NEGLECTED (INSIGNIFICANT QUANTITY NOT AFFECTING MATERIAL BALANCE)
SOLIDS & LIQUIDS ———
GASES – – –
SCFM MEASURED AT 32°F AND ONE ATMOSPHERE

BASIS:
TONNAGES ARE GIVEN FOR A 24-HOUR PERIO IN SHORT TONS

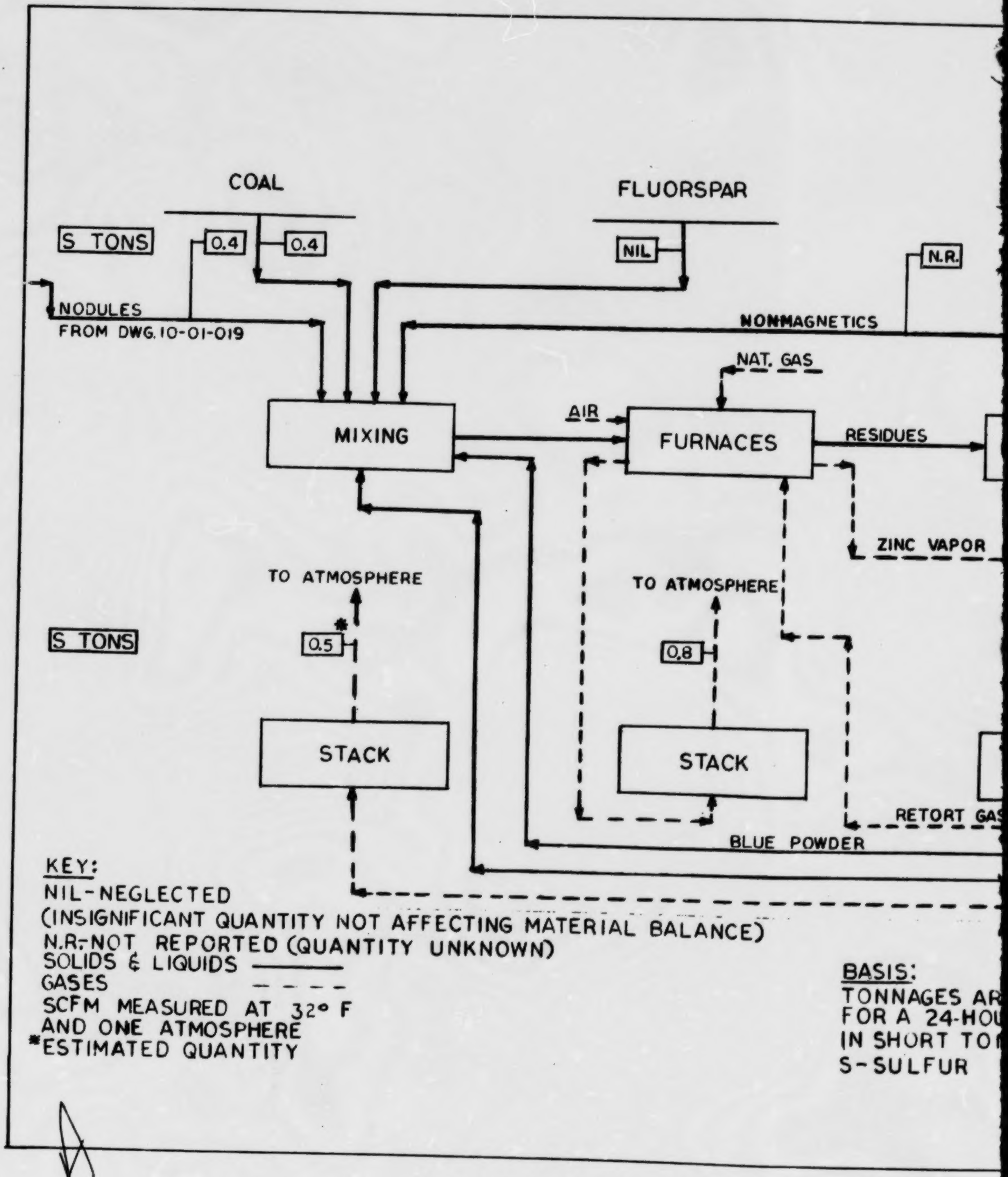
S-SULFUR


COAL
NIL
2.4
NIL
182.
AIR
FURNACES
ZINC PRODUCT
RESIDUE 664. TONS
S CONTENT 2.4 TONS
TO ATMOSPHERE
TO ATMOSPHERE
STACK
STACK
B
CADMIUM PRODUCT
S CONTENT NIL TONS

BASIS:
TONNAGES ARE GIVEN
FOR A 24-HOUR PERIOD
IN SHORT TONS

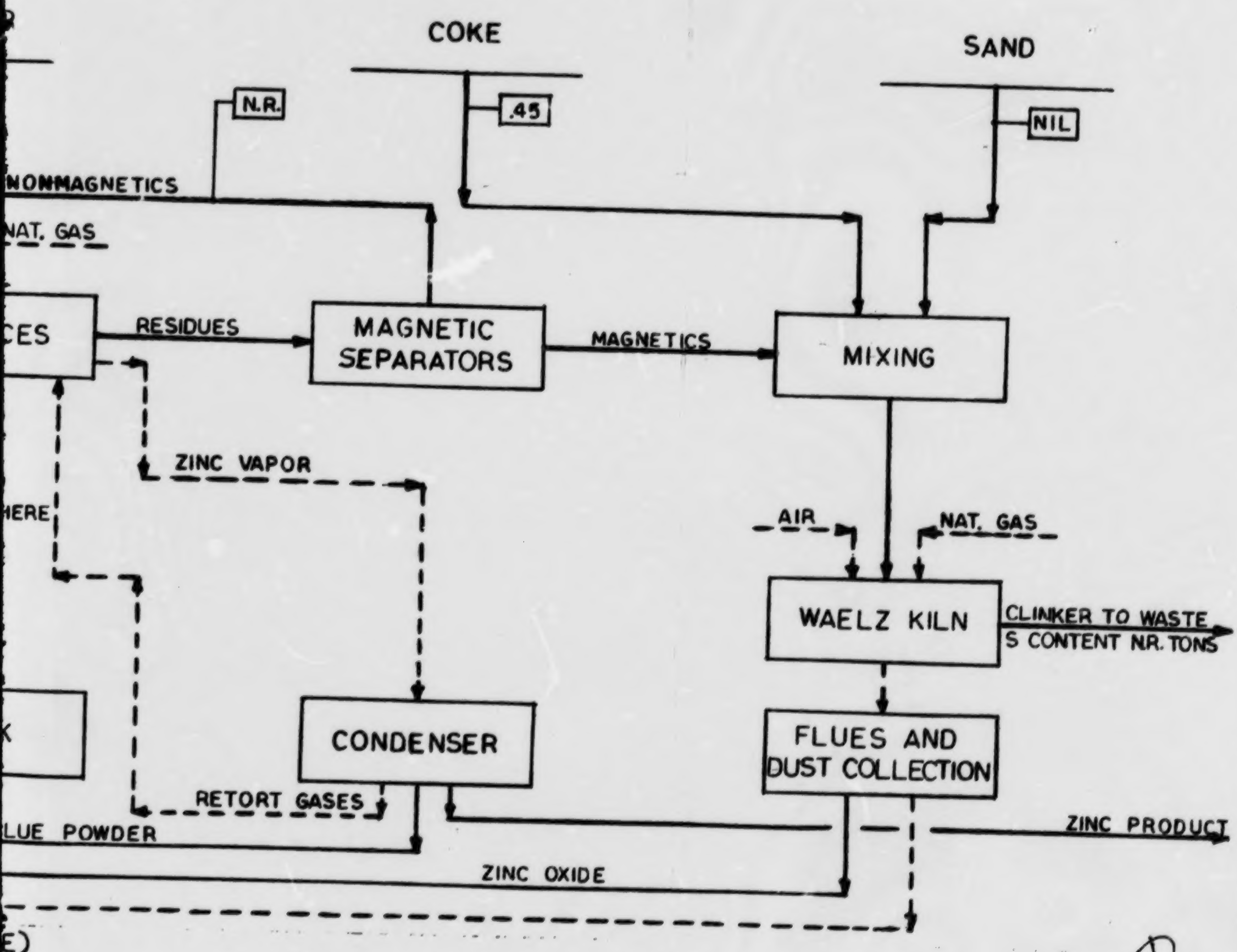
S-SULFUR

CLIENT NATIONAL AIR POLLUTION CONTROL ADMINISTRATION	ARTHUR G. McKEE & COMPANY WESTERN KNAPP ENGINEERING DIVISION SAN FRANCISCO CALIFORNIA
TITLE 326.25 ZINC PLANT FLOW DIAGRAM	ENG. DEPT. DWG. 10-01-078 PLATE NO. A-25


COAL
FLUORSPAR
S TONS
0.4
0.4
NIL
N.R.
NODULES
FROM DWG. 10-01-019
NONMAGNETICS
NAT. GAS
AIR
MIXING
FURNACES
RESIDUES
ZINC VAPOR
TO ATMOSPHERE
TO ATMOSPHERE
S TONS
0.5
*
0.8
STACK
STACK
RETORT GAS
BLUE POWDER

KEY:
NIL-NEGLECTED
(INSIGNIFICANT QUANTITY NOT AFFECTING MATERIAL BALANCE)
N.R.-NOT REPORTED (QUANTITY UNKNOWN)
SOLIDS & LIQUIDS ———
GASES – – – –
SCFM MEASURED AT 32° F
AND ONE ATMOSPHERE
*ESTIMATED QUANTITY

BASIS:
TONNAGES AR
FOR A 24-HOU
IN SHORT TO
S-SULFUR


COKE
SAND
N.R.
.45
NIL
NONMAGNETICS
NAT. GAS
CES
RESIDUES
MAGNETIC SEPARATORS
MAGNETICS
MIXING
ZINC VAPOR
HERE
AIR
NAT. GAS
WAELZ KILN
CLINKER TO WASTE
S CONTENT N.R. TONS
K
CONDENSER
FLUES AND DUST COLLECTION
RETORT GASES
LUE POWDER
ZINC PRODUCT
ZINC OXIDE
E)

B

BASIS:
TONNAGES ARE GIVEN
FOR A 24-HOUR PERIOD
IN SHORT TONS
S-SULFUR

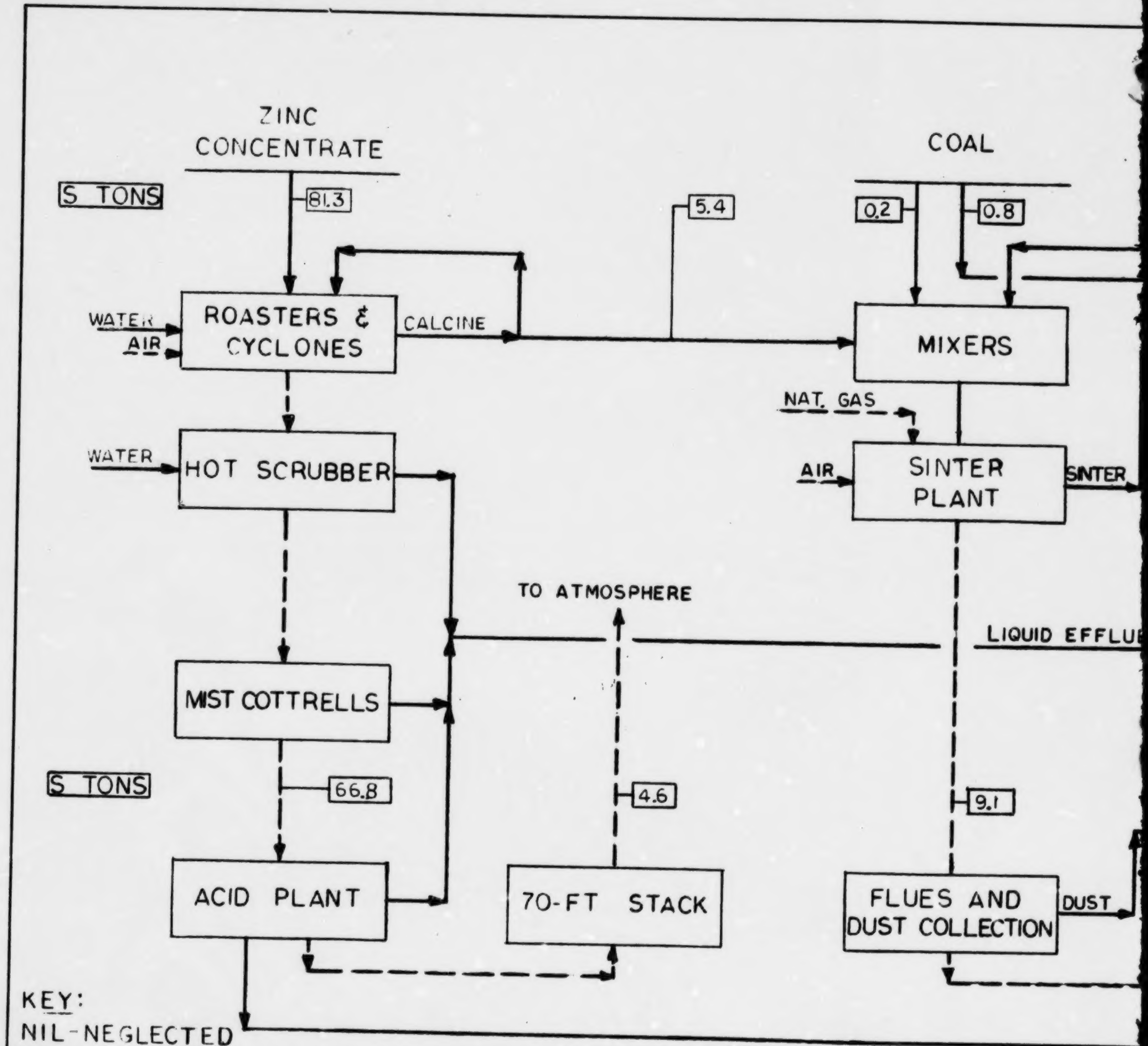
CLIENT
NATIONAL AIR
POLLUTION CONTROL
ADMINISTRATION

TITLE
326.26
ZINC PLANT
FLOW DIAGRAM

ARTHUR G. McKEE & COMPANY
WESTERN KNAPP ENGINEERING DIVISION
SAN FRANCISCO CALIFORNIA

ENG. DEPT. DWG. 10-01-03

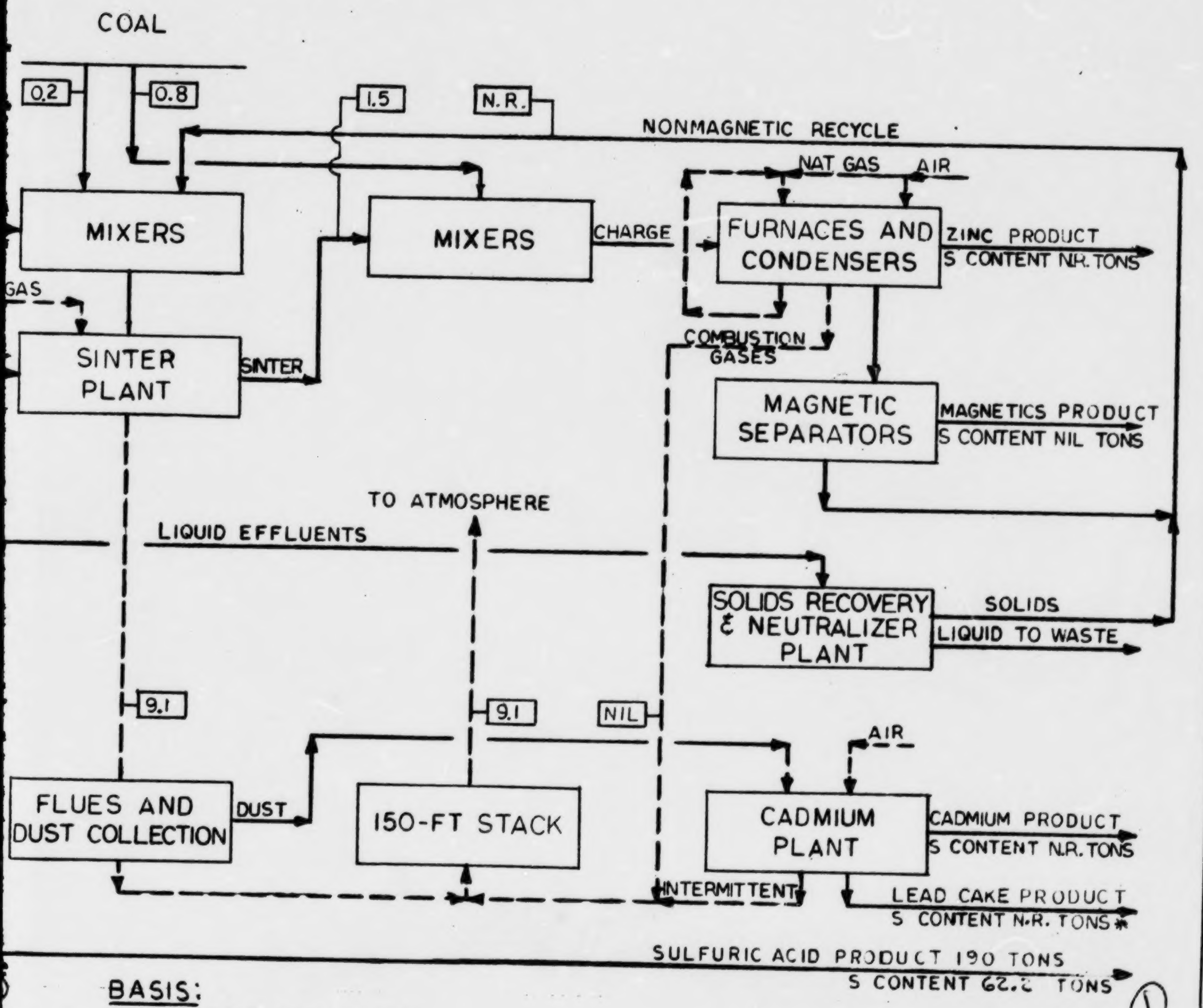
PLATE NO. A-26


ZINC CONCENTRATE
S TONS
81.3
COAL
0.2
0.8
5.4
WATER
AIR
ROASTERS & CYCLONES
CALCINE
MIXERS
NAT. GAS
WATER
HOT SCRUBBER
AIR
SINTER PLANT
SINTER
TO ATMOSPHERE
LIQUID EFFLU
MIST COTTRELLS
S TONS
66.8
4.6
9.1
ACID PLANT
70-FT STACK
FLUES AND DUST COLLECTION
DUST

KEY:
NIL-NEGLECTED
(INSIGNIFICANT QUANTITY NOT AFFECTING MATERIAL BALANCE)
N.R. NOT REPORTED (QUANTITY UNKNOWN)
SOLIDS & LIQUIDS ———
GASES - - - -
*ESTIMATED QUANTITY

BASIS:
TONNAGES ARE
FOR A 24-HOU
IN SHORT TON

S-SULFUR


COAL
0.2
0.8
1.5
N.R.
NONMAGNETIC RECYCLE
NAT GAS
AIR
MIXERS
MIXERS
CHARGE
FURNACES AND CONDENSERS
ZINC PRODUCT
S CONTENT N.R. TONS
GAS
SINTER PLANT
SINTER
COMBUSTION GASES
MAGNETIC SEPARATORS
MAGNETICS PRODUCT
S CONTENT NIL TONS
TO ATMOSPHERE
LIQUID EFFLUENTS
SOLIDS RECOVERY & NEUTRALIZER PLANT
SOLIDS
LIQUID TO WASTE
9.1
9.1
NIL
AIR
FLUES AND DUST COLLECTION
DUST
150-FT STACK
CADMIUM PLANT
CADMIUM PRODUCT
S CONTENT N.R. TONS
INTERMITTENT
LEAD CAKE PRODUCT
S CONTENT N.R. TONS *
SULFURIC ACID PRODUCT 190 TONS
S CONTENT 62.2 TONS

B

BASIS:

TONNAGES ARE GIVEN
FOR A 24-HOUR PERIOD
IN SHORT TONS

S-SULFUR

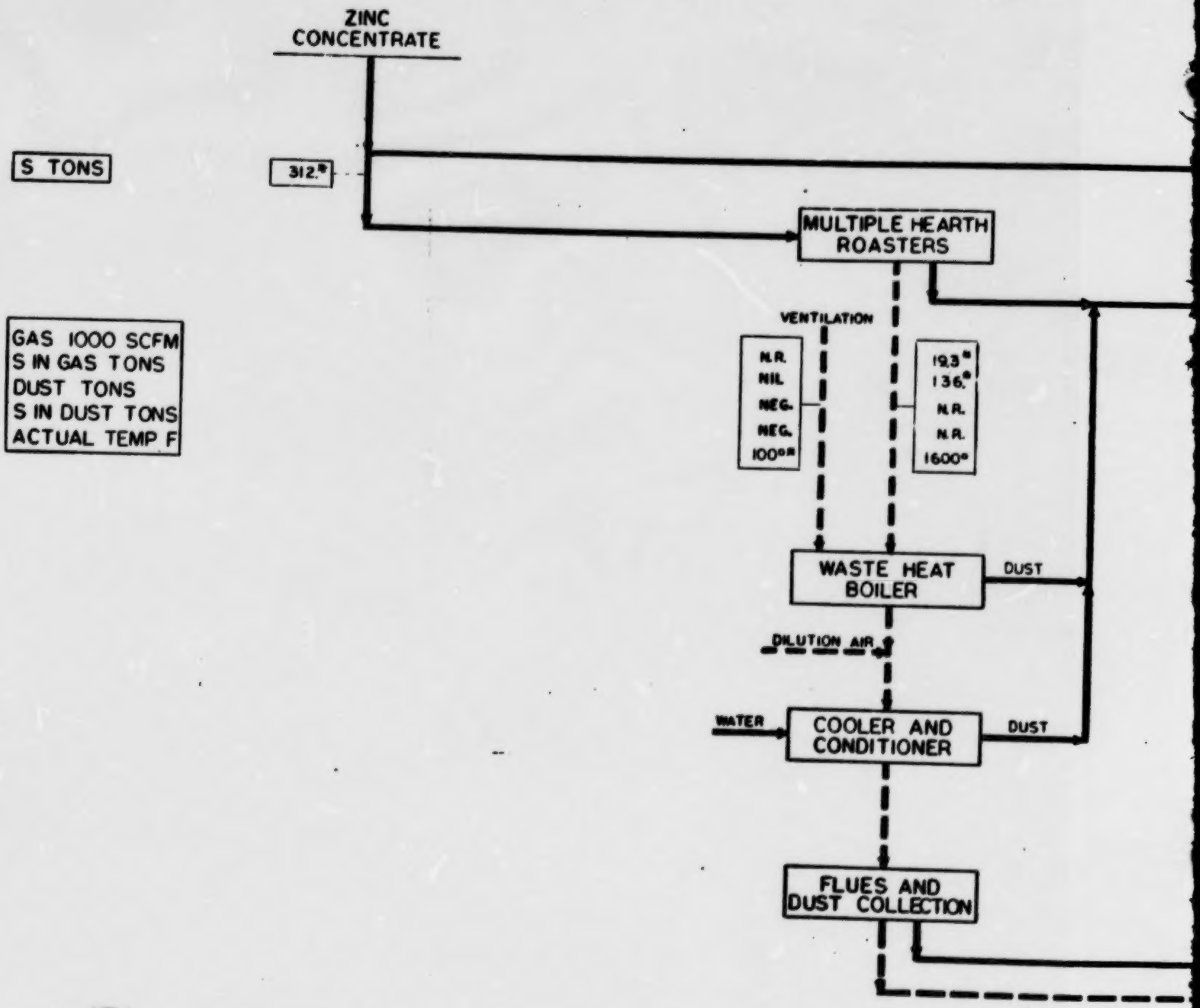
CLIENT
NATIONAL AIR
POLLUTION CONTROL
ADMINISTRATION

TITLE
326.27
ZINC PLANT
FLOW DIAGRAM

ARTHUR G. McKEE & COMPANY
WESTERN KNAPP ENGINEERING DIVISION
SAN FRANCISCO CALIFORNIA

ENG. DEPT. DWG. 10-01-031

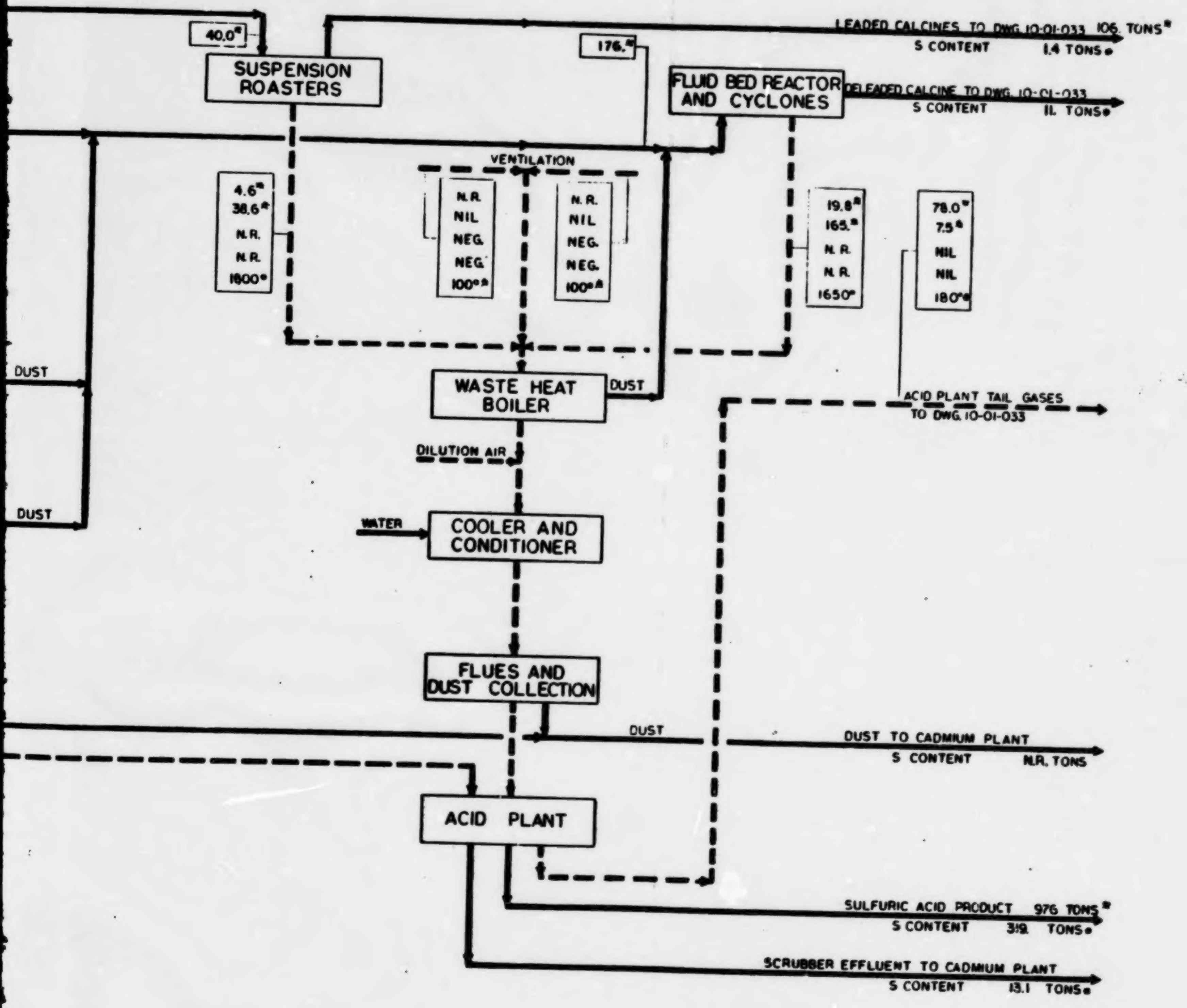
PLATE NO. A-27


ZINC CONCENTRATE
S TONS
312.*
GAS 1000 SCFM
S IN GAS TONS
DUST TONS
S IN DUST TONS
ACTUAL TEMP F
MULTIPLE HEARTH ROASTERS
VENTILATION
N.R.
NIL
NEG.
NEG.
100°*
19.3*
136.*
N.R.
N.R.
1600°
WASTE HEAT BOILER
DUST
DILUTION AIR
WATER
COOLER AND CONDITIONER
DUST
FLUES AND DUST COLLECTION

KEY
SOLIDS & LIQUIDS ————
GASES – – – –
SCFM MEASURED AT 32°F AND ONE ATMOSPHERE
NIL - NEGLECTED (INSIGNIFICANT QUANTITY NOT AFFECTING MATERIAL BALANCE)
NEG.- NEGLECTED (MINOR QUANTITY PRESENT, BUT NOT REPORTED OR ESTIMATED)
N.R. - NOT REPORTED (QUANTITY UNKNOWN)
* - ESTIMATED QUANTITY

BASIS:
TONNAGES ARE GIVEN
FOR A 24-HOUR PERIOD
IN SHORT TONS

S-SULFUR


40.0*
SUSPENSION ROASTERS
176.*
FLUID BED REACTOR AND CYCLONES
LEADED CALCINES TO DWG 10-01-033 106. TONS*
S CONTENT 1.4 TONS●
DELEADED CALCINE TO DWG. 10-01-033
S CONTENT 11. TONS●
VENTILATION
4.6*
38.6*
N.R.
N.R.
1800°
N.R.
NIL
NEG.
NEG.
100°*
N.R.
NIL
NEG.
NEG.
100°*
19.8*
165.*
N.R.
N.R.
1650°
78.0*
7.5*
NIL
NIL
180°*
DUST
DUST
WASTE HEAT BOILER
DUST
ACID PLANT TAIL GASES TO DWG. 10-01-033
DILUTION AIR
WATER
COOLER AND CONDITIONER
FLUES AND DUST COLLECTION
DUST
DUST TO CADMIUM PLANT
S CONTENT N.R. TONS
ACID PLANT
SULFURIC ACID PRODUCT 976 TONS*
S CONTENT 319. TONS●
SCRUBBER EFFLUENT TO CADMIUM PLANT
S CONTENT 13.1 TONS●
N
OD

B

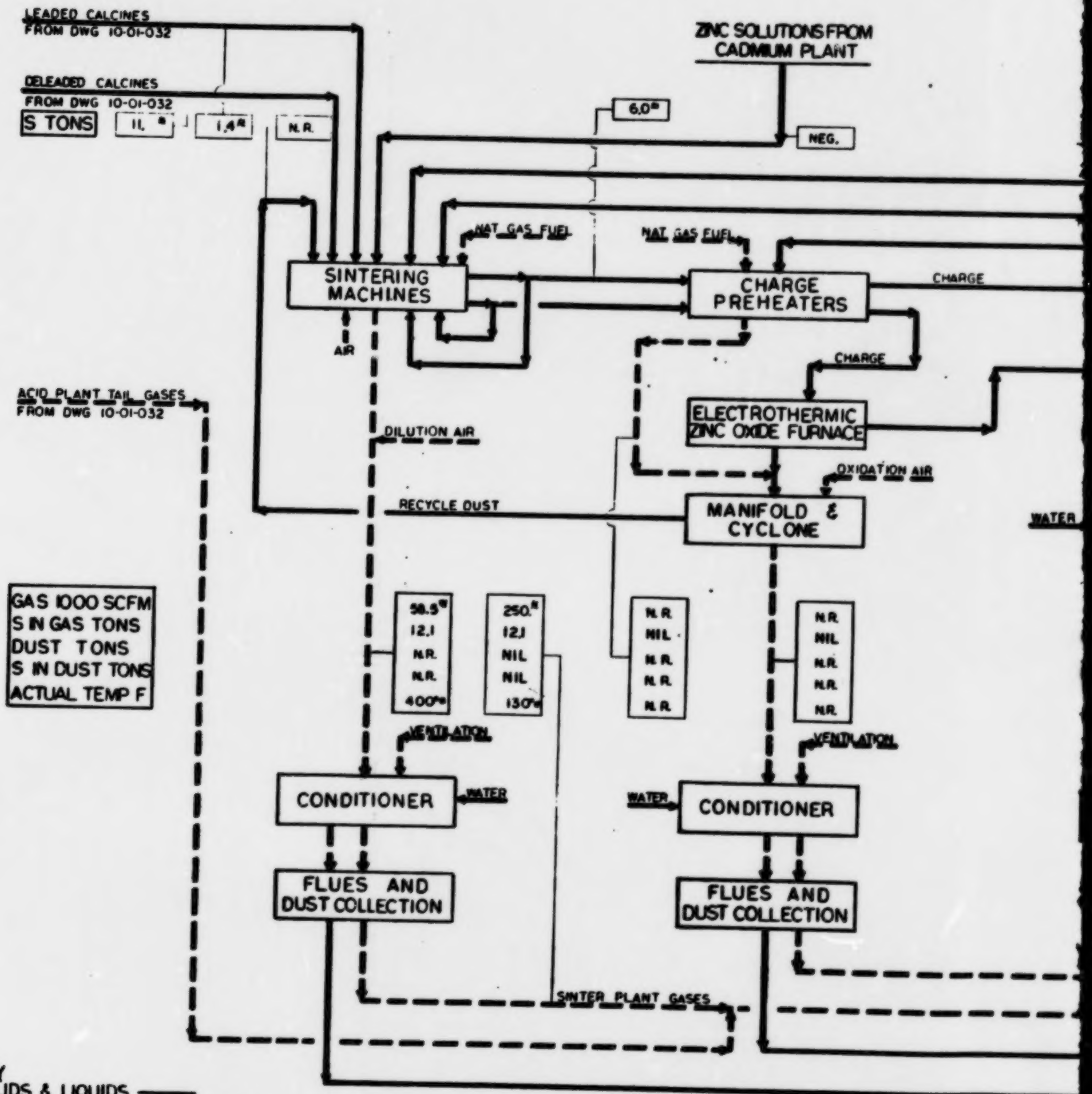
NATIONAL AIR
POLLUTION CONTROL
ADMINISTRATION

326.28
ZINC PLANT
FLOW DIAGRAM

ARTHUR G. McKEE & COMPANY
WESTERN KNAPP ENGINEERING DIVISION
SAN FRANCISCO CALIFORNIA

ENG. DEPT. DWG. 10-01-032

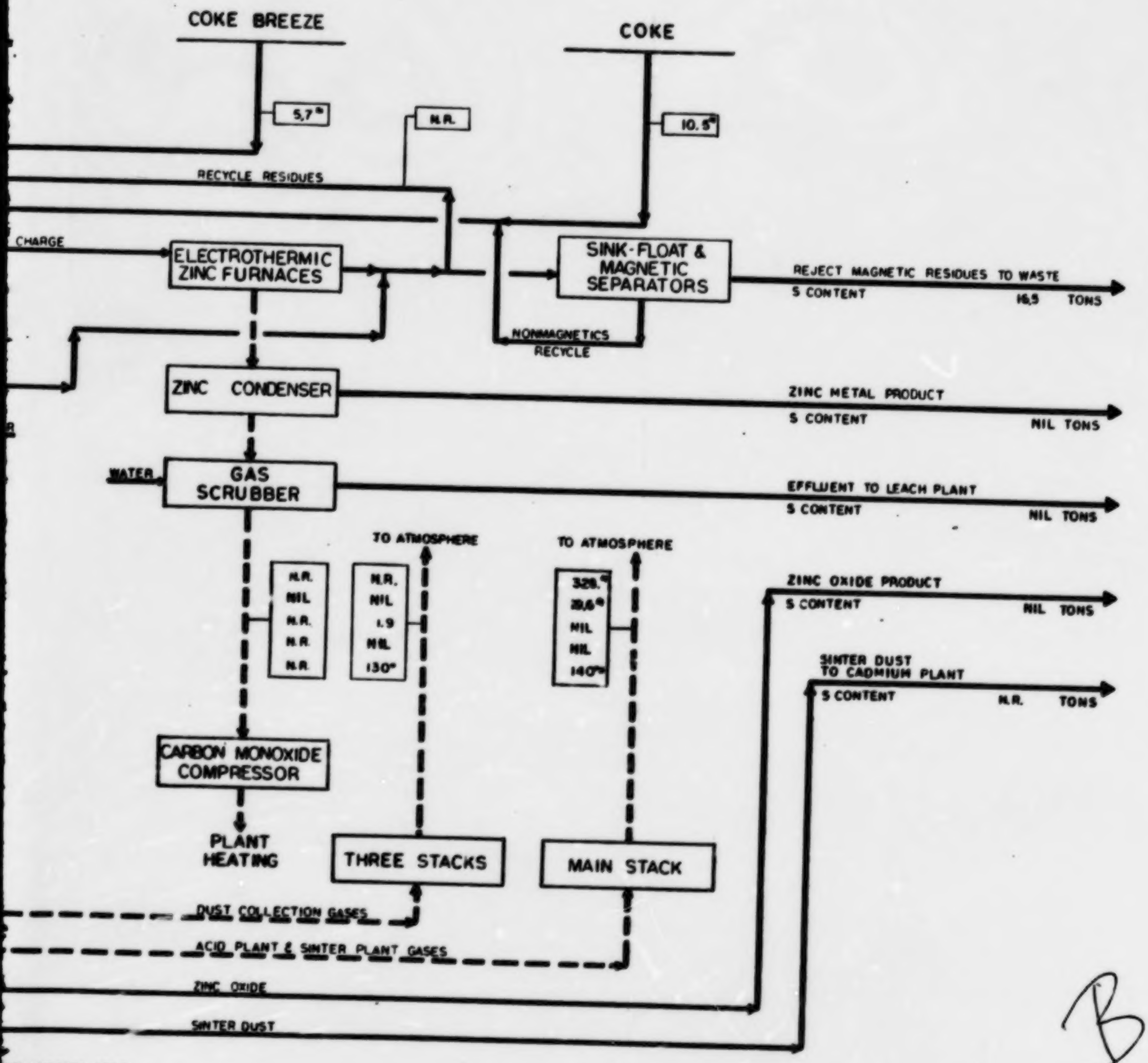
PLATE NO. A-28


LEADED CALCINES
FROM DWG 10-01-032
DELEADED CALCINES
FROM DWG 10-01-032
S TONS
11.*
1.4*
N.R.
6.0*
ZINC SOLUTIONS FROM
CADMIUM PLANT
NEG.
NAT GAS FUEL
NAT GAS FUEL
SINTERING
MACHINES
CHARGE
PREHEATERS
CHARGE
CHARGE
AIR
ACID PLANT TAIL GASES
FROM DWG 10-01-032
DILUTION AIR
ELECTROTHERMIC
ZINC OXIDE FURNACE
OXIDATION AIR
RECYCLE DUST
MANIFOLD &
CYCLONE
WATER
GAS 1000 SCFM
S IN GAS TONS
DUST TONS
S IN DUST TONS
ACTUAL TEMP F
58.5*
12.1
N.R.
N.R.
400*
250.*
12.1
NIL
NIL
130*
N.R.
NIL
N.R.
N.R.
N.R.
N.R.
NIL
N.R.
N.R.
N.R.
VENTILATION
VENTILATION
CONDITIONER
WATER
WATER
CONDITIONER
FLUES AND
DUST COLLECTION
FLUES AND
DUST COLLECTION
SINTER PLANT GASES

KEY
SOLIDS & LIQUIDS ———
GASES – – –
SCFM MEASURED AT 32°F AND ONE ATMOSPHERE
NIL - NEGLECTED(UNSIGNIFICANT QUANTITY NOT AFFECTING MATERIAL BALANCE)
NEG. - NEGLECTED(MINOR QUANTITY PRESENT, BUT NOT REPORTED OR ESTIMATED)
N.R. - NOT REPORTED(QUANTITY UNKNOWN)
* - ESTIMATED QUANTITY

BASIS:
TONNAGES ARE GIVEN FOR A 24-HOUR PERIOD IN SHORT TONS

S-SULFUR


COKE BREEZE
5.7*
N.R.
COKE
10.5*
RECYCLE RESIDUES
CHARGE
ELECTROTHERMIC ZINC FURNACES
SINK-FLOAT & MAGNETIC SEPARATORS
REJECT MAGNETIC RESIDUES TO WASTE
S CONTENT 16.5 TONS
NONMAGNETICS RECYCLE
ZINC CONDENSER
ZINC METAL PRODUCT
S CONTENT NIL TONS
WATER
GAS SCRUBBER
EFFLUENT TO LEACH PLANT
S CONTENT NIL TONS
N.R.
NIL
N.R.
N.R.
N.R.
TO ATMOSPHERE
N.R.
NIL
1.9
NIL
130*
TO ATMOSPHERE
328.*
29.6*
NIL
NIL
140*
ZINC OXIDE PRODUCT
S CONTENT NIL TONS
SINTER DUST TO CADMIUM PLANT
S CONTENT N.R. TONS
CARBON MONOXIDE COMPRESSOR
PLANT HEATING
THREE STACKS
MAIN STACK
DUST COLLECTION GASES
ACID PLANT & SINTER PLANT GASES
ZINC OXIDE
SINTER DUST

B

RE GIVEN FOR
ERIOD IN

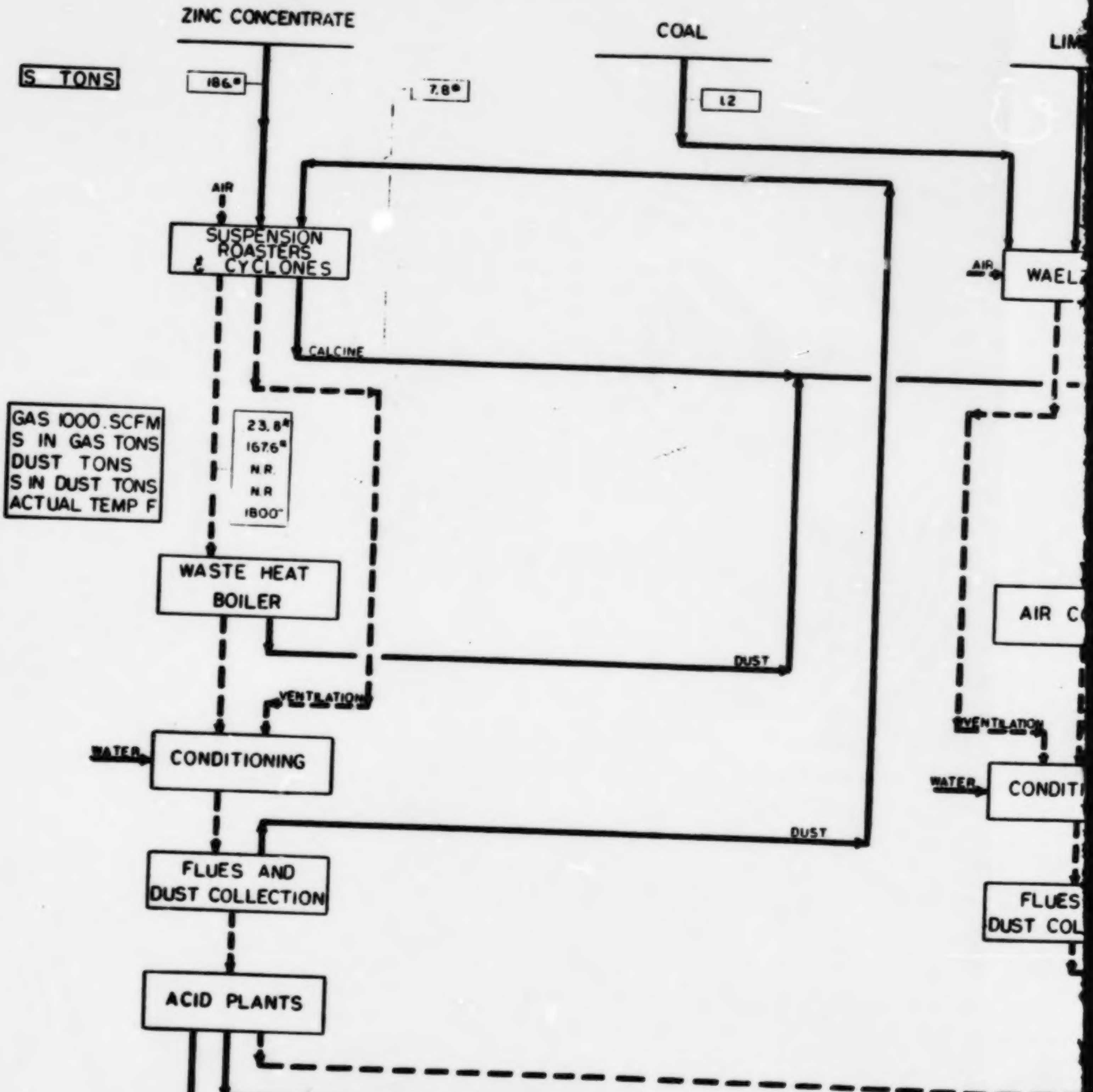
NATIONAL AIR
POLLUTION CONTROL
ADMINISTRATION

326.28
ZINC PLANT
FLOW DIAGRAM

ARTHUR G. McKEE & COMPANY
WESTERN KNAPP ENGINEERING DIVISION
SAN FRANCISCO CALIFORNIA

ENG. DEPT. DWG. 10-01-033

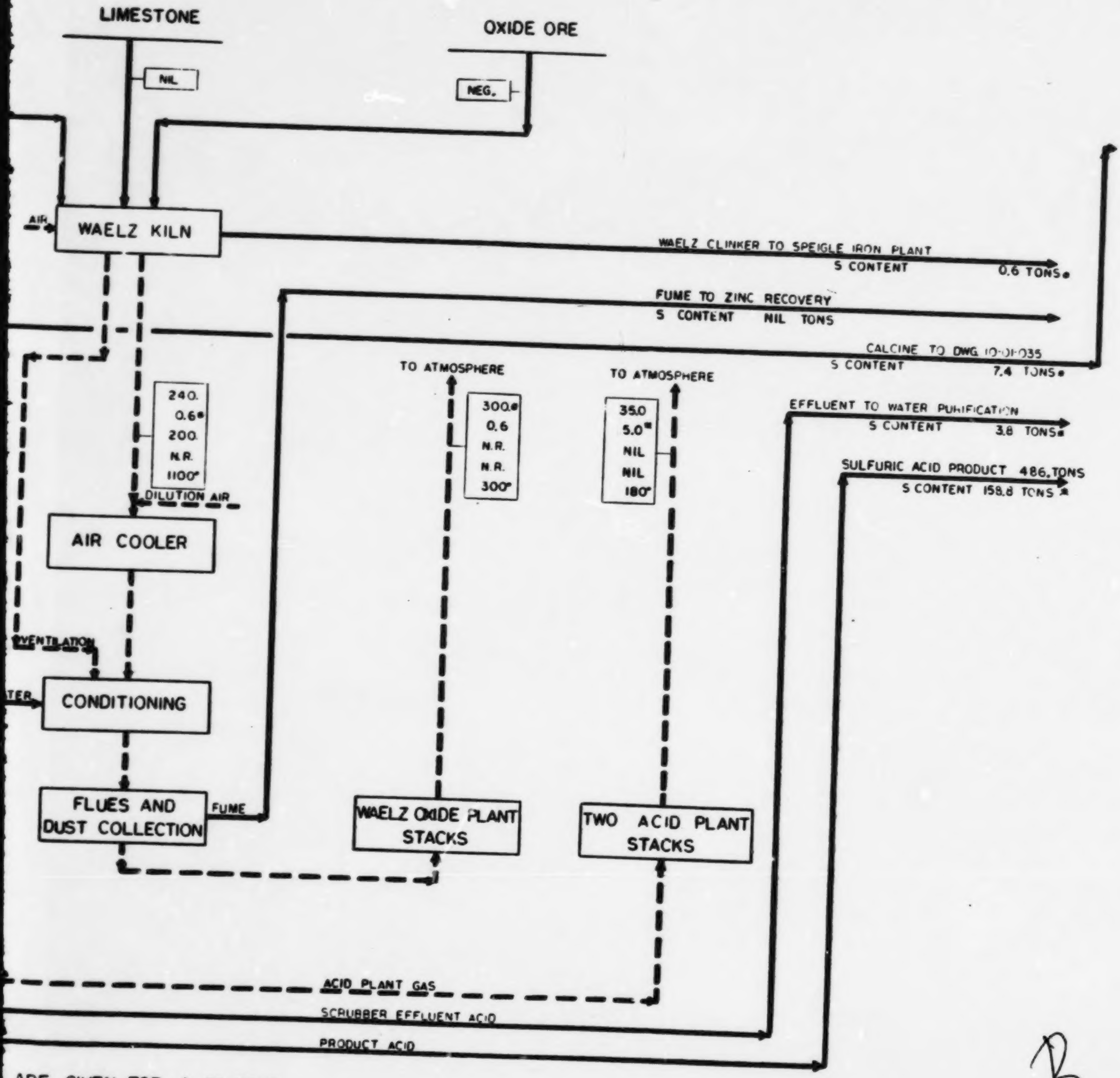
PLATE NO. A-29


ZINC CONCENTRATE
COAL
LIM
S TONS
186*
7.8*
12
AIR
SUSPENSION ROASTERS & CYCLONES
AIR
WAEL
CALCINE
GAS 1000.SCFM
S IN GAS TONS
DUST TONS
S IN DUST TONS
ACTUAL TEMP F
23.8*
167.6*
N.R.
N.R
1800°
WASTE HEAT BOILER
AIR C
DUST
VENTILATION
VENTILATION
WATER
CONDITIONING
WATER
CONDIT
DUST
FLUES AND DUST COLLECTION
FLUES
DUST COL
ACID PLANTS

KEY:
SOLIDS & LIQUIDS ————
GASES – – – –
SCFM MEASURED AT 32°F AND ONE ATMOSPHERE
NIL - NEGLECTED (INSIGNIFICANT QUANTITY NOT AFFECTING MATERIAL BALANCE)
NEG - NEGLECTED (MINOR QUANTITY PRESENT, BUT NOT REPORTED OR ESTIMATED)
N.R. - NOT REPORTED (QUANTITY UNKNOWN)
* - ESTIMATED QUANTITY

BASIS:
TONNAGES ARE GIVEN
PERIOD IN SHORT TONS
S-SULFUR

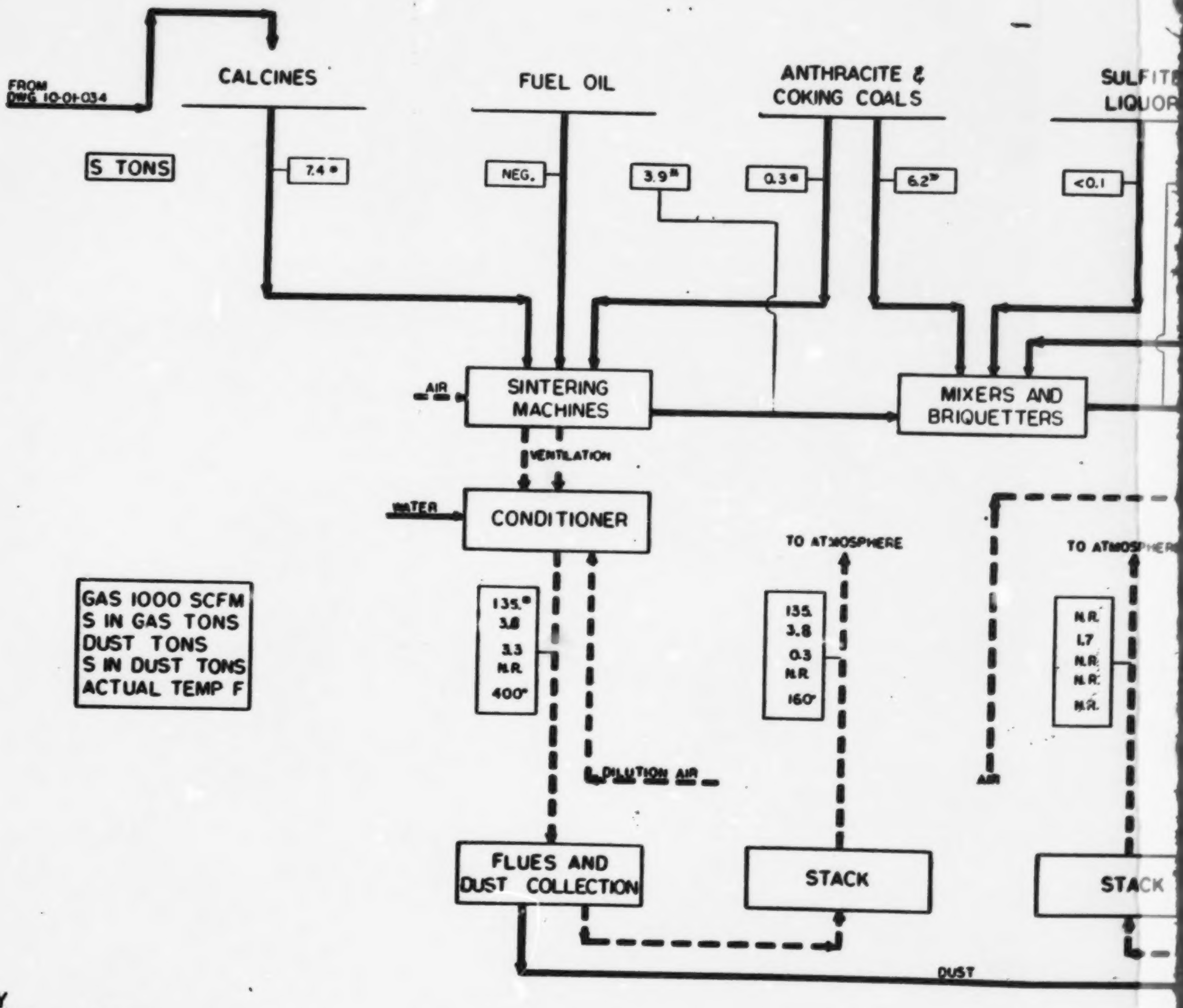
A


LIMESTONE
NIL
OXIDE ORE
NEG.
AIR
WAELZ KILN
WAELZ CLINKER TO SPEIGLE IRON PLANT
S CONTENT 0.6 TONS*
FUME TO ZINC RECOVERY
S CONTENT NIL TONS
CALCINE TO DWG 10-01-035
S CONTENT 7.4 TONS*
240.
0.6*
200.
N.R.
1100°
DILUTION AIR
AIR COOLER
TO ATMOSPHERE
300.*
0.6
N.R.
N.R.
300°
TO ATMOSPHERE
35.0
5.0*
NIL
NIL
180°
EFFLUENT TO WATER PURIFICATION
S CONTENT 3.8 TONS*
SULFURIC ACID PRODUCT 486. TONS
S CONTENT 158.8 TONS *
VENTILATION
TER
CONDITIONING
FLUES AND DUST COLLECTION
FUME
WAELZ OXIDE PLANT STACKS
TWO ACID PLANT STACKS
ACID PLANT GAS
SCRUBBER EFFLUENT ACID
PRODUCT ACID

ARE GIVEN FOR A 24 HOUR
SHORT TONS

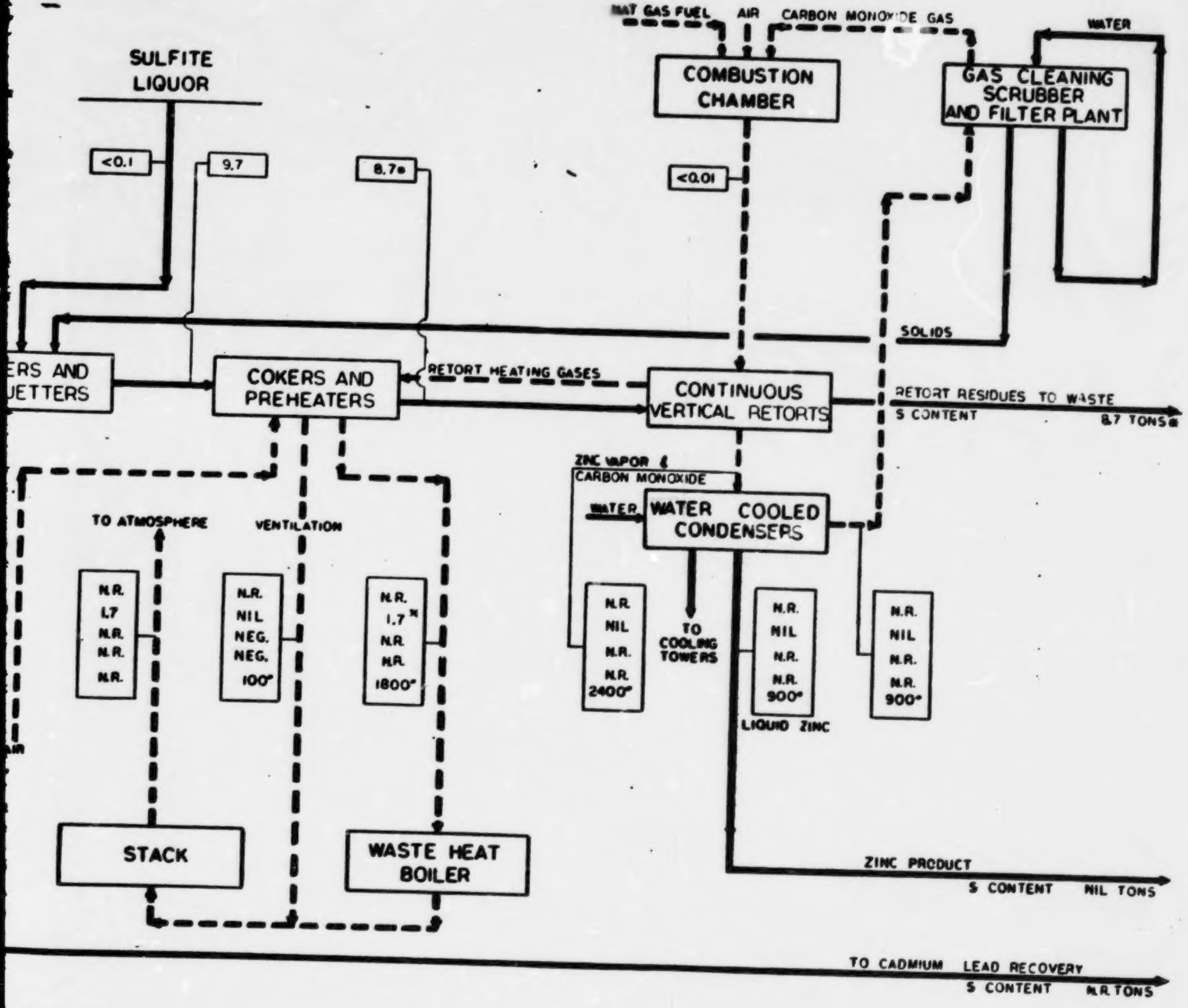
B

NATIONAL AIR POLLUTION CONTROL ADMINISTRATION	ARTHUR G. McKEE & COMPANY WESTERN KNAPP ENGINEERING DIVISION SAN FRANCISCO CALIFORNIA
326.29 ZINC PLANT FLOW DIAGRAM	ENG. DEPT. DWG. 10-01-034 **PLATE NO. A30**


FROM DWG 10-01-034
CALCINES
FUEL OIL
ANTHRACITE & COKING COALS
SULFITE LIQUOR
S TONS
7.4*
NEG.
3.9*
0.3*
6.2*
<0.1
AIR
SINTERING MACHINES
MIXERS AND BRIQUETTERS
VENTILATION
WATER
CONDITIONER
TO ATMOSPHERE
TO ATMOSPHERE
GAS 1000 SCFM
S IN GAS TONS
DUST TONS
S IN DUST TONS
ACTUAL TEMP F
135.*
3.8
3.3
N.R.
400°
135
3.8
0.3
N.R.
160°
N.R.
1.7
N.R.
N.R.
N.R.
DILUTION AIR
AIR
FLUES AND DUST COLLECTION
STACK
STACK
DUST

KEY
SOLIDS & LIQUIDS ———
GASES – – –
SCFM MEASURED AT 32°F AND ONE ATMOSPHERE
NIL - NEGLECTED (INSIGNIFICANT QUANTITY NOT AFFECTING MATERIAL BALANCE)
NEG. - NEGLECTED (MINOR QUANTITY PRESENT, BUT NOT REPORTED OR ESTIMATED)
N.R. - NOT REPORTED (QUANTITY UNKNOWN)
* - ESTIMATED QUANTITY

A

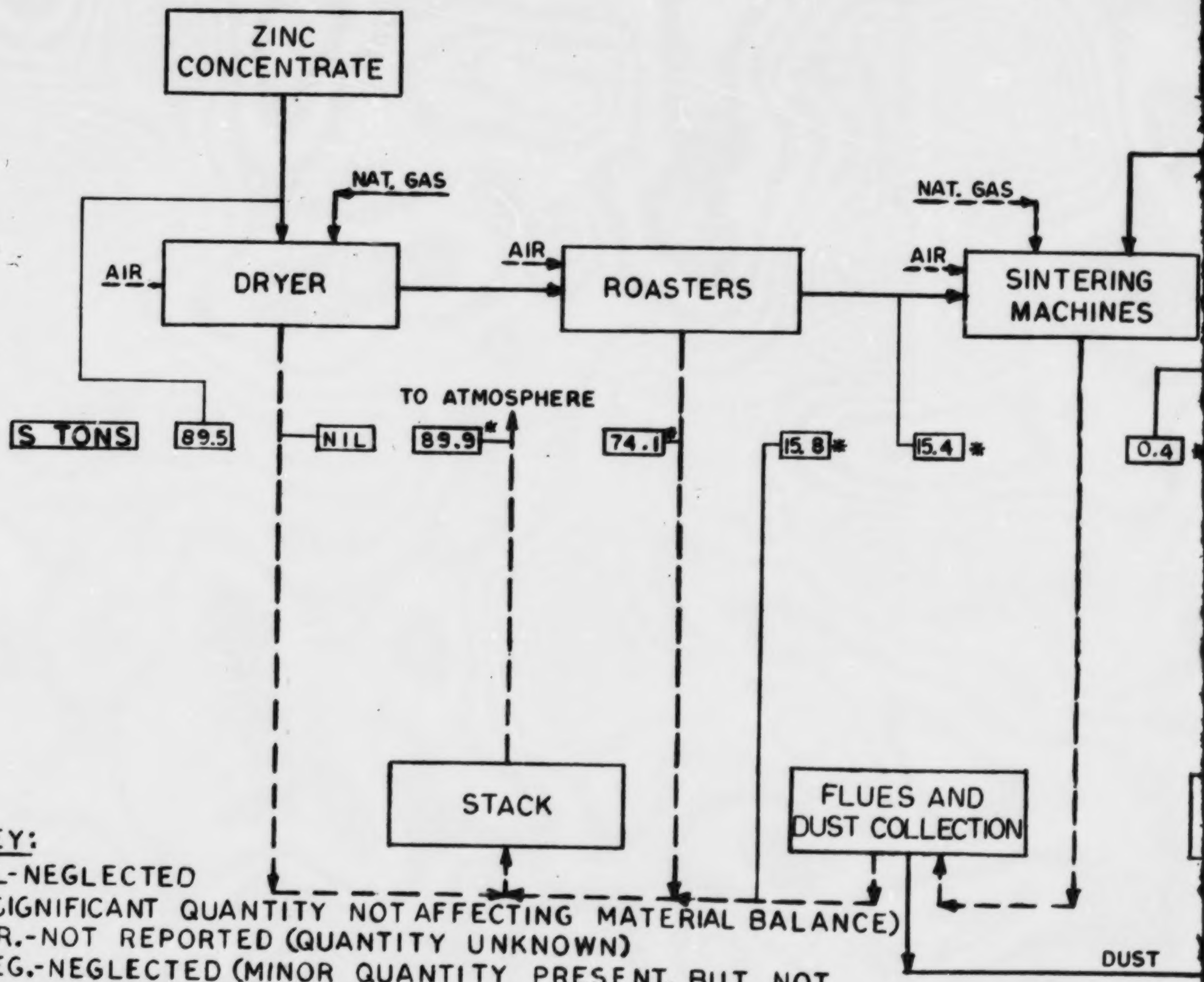

NAT GAS FUEL
AIR
CARBON MONOXIDE GAS
WATER
SULFITE LIQUOR
COMBUSTION CHAMBER
GAS CLEANING SCRUBBER AND FILTER PLANT
<0.1
9.7
8.7*
<0.01
SOLIDS
ERS AND
UETTERS
COKERS AND PREHEATERS
RETORT HEATING GASES
CONTINUOUS VERTICAL RETORTS
RETORT RESIDUES TO WASTE
S CONTENT 8.7 TONS*
ZINC VAPOR & CARBON MONOXIDE
WATER
WATER COOLED CONDENSERS
TO ATMOSPHERE
VENTILATION
N.R.
1.7
N.R.
N.R.
N.R.
N.R.
NIL
NEG.
NEG.
100°
N.R.
1.7*
N.R.
N.R.
1800°
N.R.
NIL
N.R.
N.R.
2400°
TO COOLING TOWERS
N.R.
NIL
N.R.
N.R.
900°
LIQUID ZINC
N.R.
NIL
N.R.
N.R.
900°
AIR
STACK
WASTE HEAT BOILER
ZINC PRODUCT
S CONTENT NIL TONS
TO CADMIUM LEAD RECOVERY
S CONTENT N.R. TONS

BASIS:
TONNAGES ARE GIVEN
FOR A 24-HOUR PERIOD
IN SHORT TONS

S-SULFUR

B

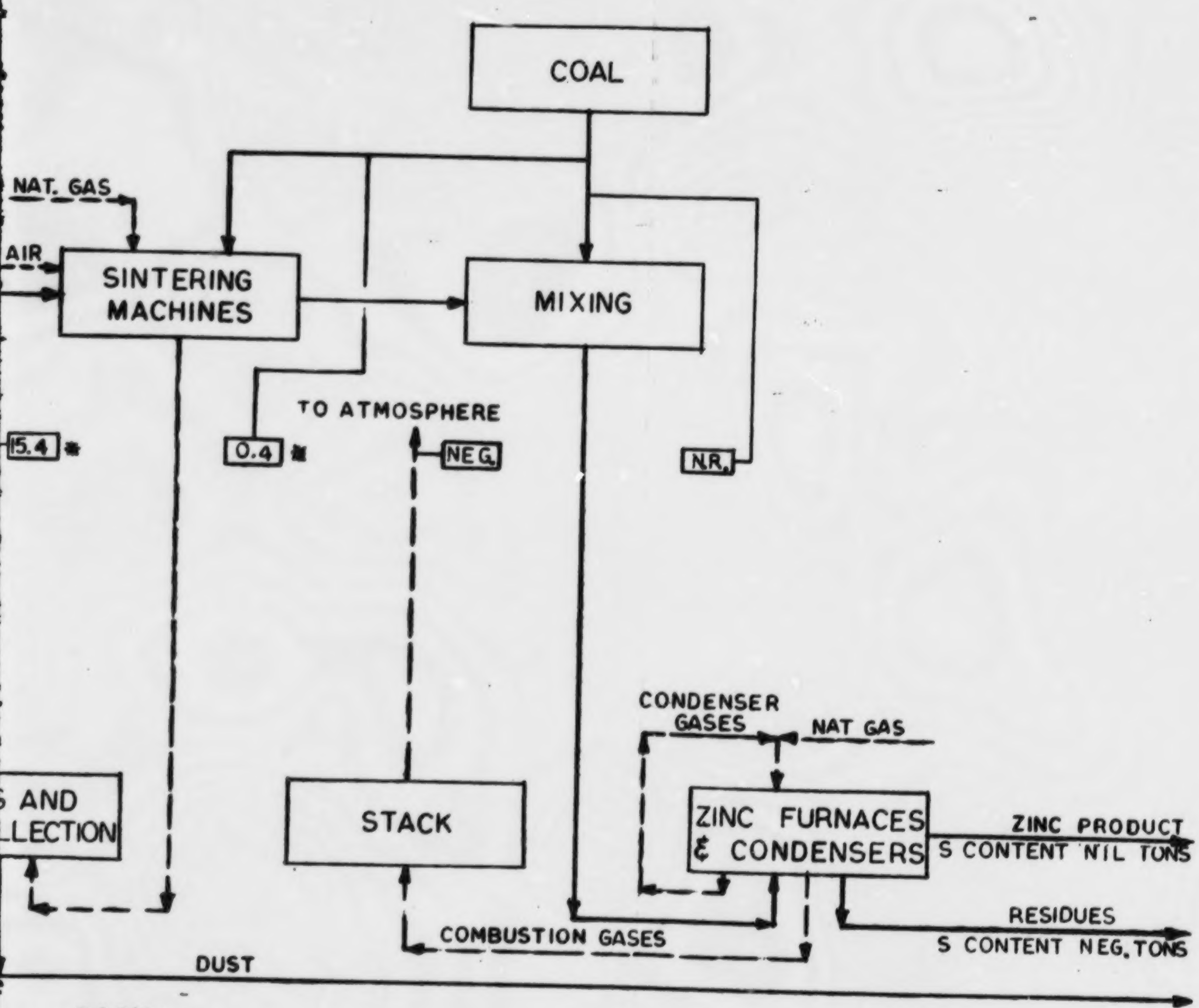
NATIONAL AIR POLLUTION CONTROL ADMINISTRATION	ARTHUR G. McKEE & COMPANY WESTERN KNAPP ENGINEERING DIVISION SAN FRANCISCO CALIFORNIA
326.29 ZINC PLANT FLOW DIAGRAM	ENG. DEPT. DWG. 10-01-035 PLATE NO. A-31


ZINC CONCENTRATE
NAT. GAS
AIR
DRYER
AIR
ROASTERS
NAT. GAS
AIR
SINTERING MACHINES
TO ATMOSPHERE
S TONS
89.5
NIL
89.9*
74.1*
15.8*
15.4*
0.4*
STACK
FLUES AND DUST COLLECTION
DUST

KEY:
NIL-NEGLECTED
(INSIGNIFICANT QUANTITY NOT AFFECTING MATERIAL BALANCE)
N.R.-NOT REPORTED (QUANTITY UNKNOWN)
NEG.-NEGLECTED (MINOR QUANTITY PRESENT, BUT NOT REPORTED OR ESTIMATED)
SOLIDS & LIQUIDS ———
GASES - - -
*ESTIMATED QUANTITY

BASIS:
TONNAGES ARE
FOR A 24-HOU
IN SHORT TON

S-SULFUR


COAL
NAT. GAS
AIR
SINTERING MACHINES
MIXING
TO ATMOSPHERE
15.4 *
0.4 *
NEG.
N.R.
CONDENSER GASES
NAT GAS
S AND
LLECTION
STACK
ZINC FURNACES & CONDENSERS
ZINC PRODUCT
S CONTENT NIL TONS
RESIDUES
S CONTENT NEG. TONS
COMBUSTION GASES
DUST

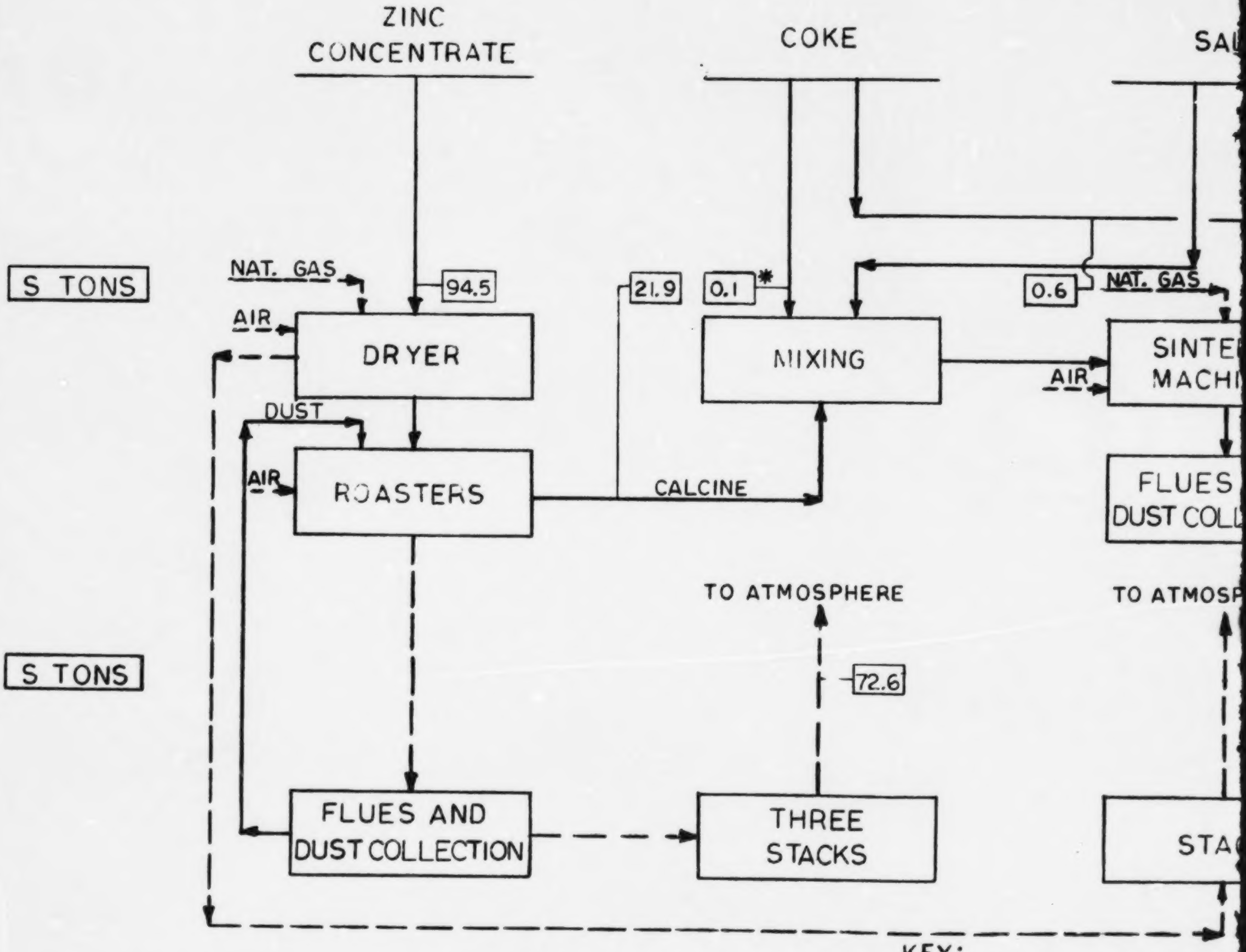
BASIS:

TONNAGES ARE GIVEN
FOR A 24-HOUR PERIOD
IN SHORT TONS

S-SULFUR

CLIENT NATIONAL AIR POLLUTION CONTROL ADMINISTRATION	**ARTHUR G. McKEE & COMPANY** WESTERN KNAPP ENGINEERING DIVISION SAN FRANCISCO CALIFORNIA
	ENG. DEPT. DWG. 10-01-0[illegible]
TITLE 326.31 ZINC PLANT FLOW DIAGRAM	PLATE NO. A-32

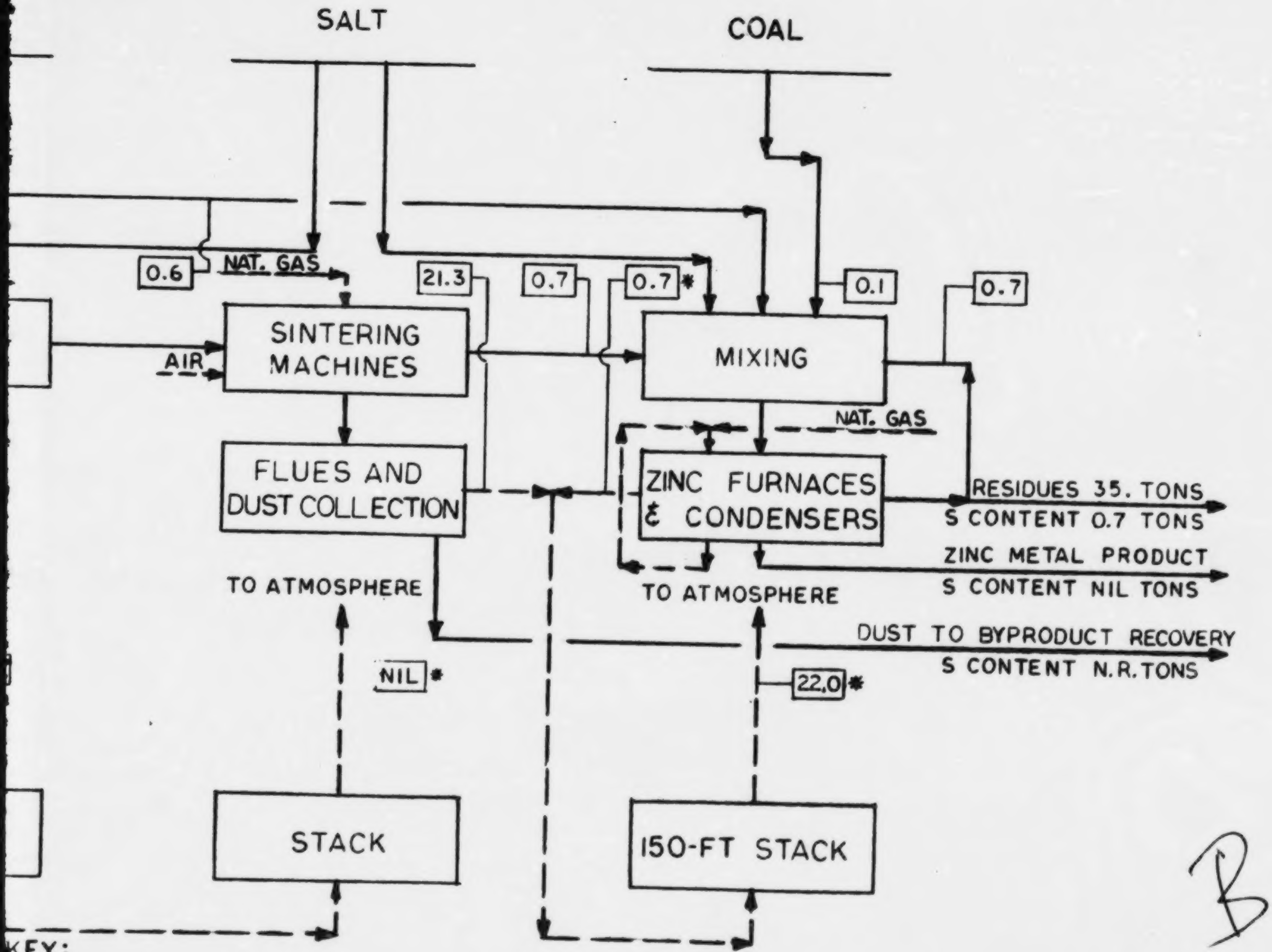
B


ZINC CONCENTRATE
COKE
SA
S TONS
NAT. GAS
AIR
94.5
DRYER
DUST
AIR
ROASTERS
21.9
0.1*
MIXING
CALCINE
0.6
NAT. GAS
AIR
SINTE
MACH
FLUES
DUST COLL
S TONS
TO ATMOSPHERE
72.6
TO ATMOS
FLUES AND DUST COLLECTION
THREE STACKS
STA

BASIS:
TONNAGES ARE GIVEN
FOR A 24-HOUR PERIOD
IN SHORT TONS

S-SULFUR

KEY:
NIL-NEGLECTED (INSIG
N.R.-NOT REPORTED (QU
SOLIDS & LIQUIDS ———
GASES — —
SCFM MEASURED AT 32
AND ONE ATMOSPHERE
*ESTIMATED QUANTITY


SALT
COAL
0.6
NAT. GAS
AIR
SINTERING MACHINES
21.3
0.7
0.7*
0.1
0.7
MIXING
NAT. GAS
FLUES AND DUST COLLECTION
ZINC FURNACES & CONDENSERS
RESIDUES 35. TONS
S CONTENT 0.7 TONS
ZINC METAL PRODUCT
S CONTENT NIL TONS
TO ATMOSPHERE
TO ATMOSPHERE
DUST TO BYPRODUCT RECOVERY
S CONTENT N.R. TONS
NIL*
22.0*
STACK
150-FT STACK

B

KEY:
NIL- NEGLECTED (INSIGNIFICANT QUANTITY NOT AFFECTING MATERIAL BALANCE)
N.R.-NOT REPORTED (QUANTITY UNKNOWN)
SOLIDS & LIQUIDS ———
GASES — — —
SCFM MEASURED AT 32° F
AND ONE ATMOSPHERE
*ESTIMATED QUANTITY

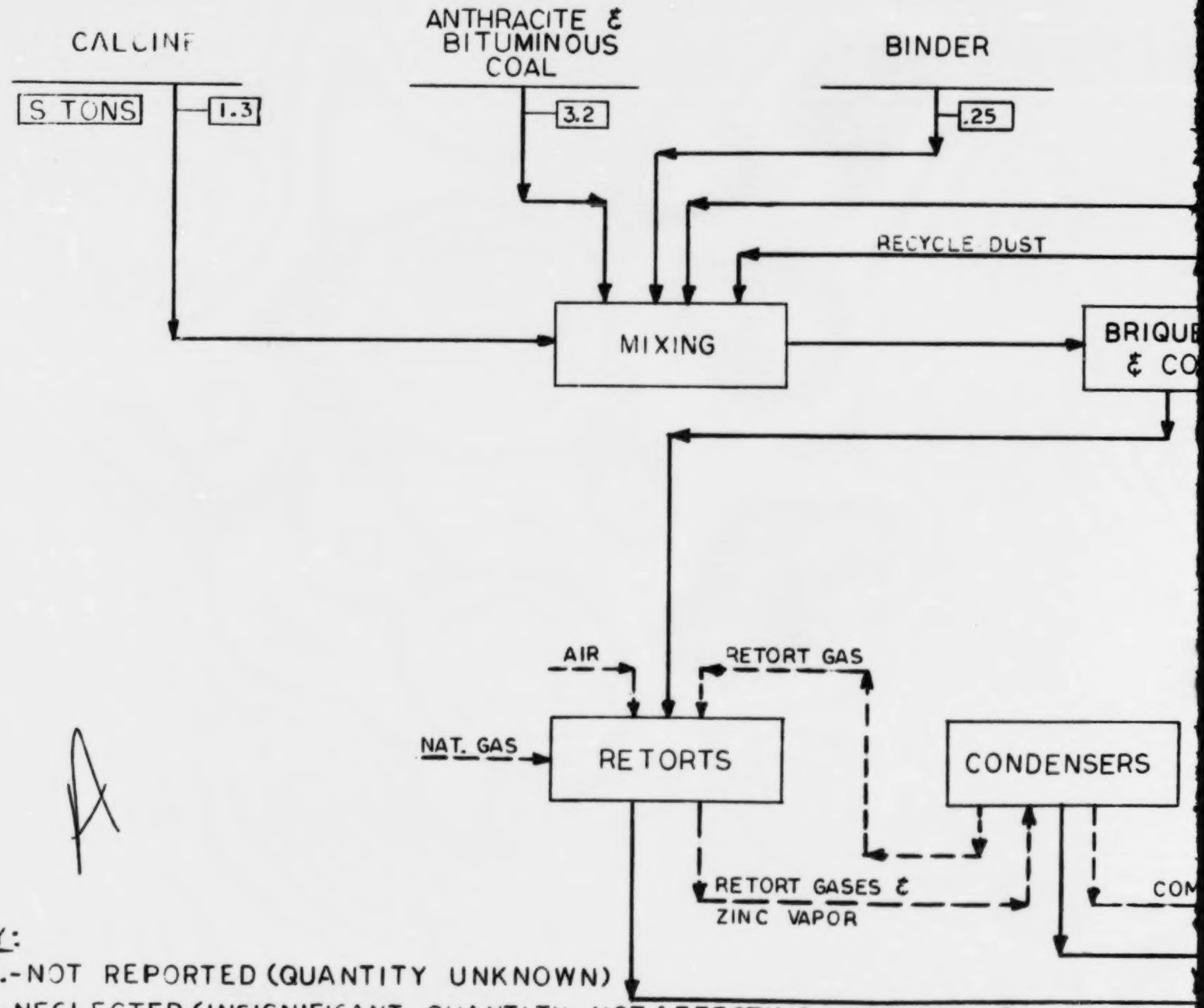
CLIENT
NATIONAL AIR
POLLUTION CONTROL
ADMINISTRATION

ARTHUR G. McKEE & COMPANY
WESTERN KNAPP ENGINEERING DIVISION
SAN FRANCISCO CALIFORNIA

TITLE
326.32
ZINC PLANT
FLOW DIAGRAM

ENG. DEPT. DWG. 10-01-03

PLATE NO. A-33


CALCINE
S TONS
1.3
ANTHRACITE & BITUMINOUS COAL
3.2
BINDER
.25
RECYCLE DUST
MIXING
BRIQUE
& CO
AIR
RETORT GAS
NAT. GAS
RETORTS
CONDENSERS
RETORT GASES & ZINC VAPOR
COM

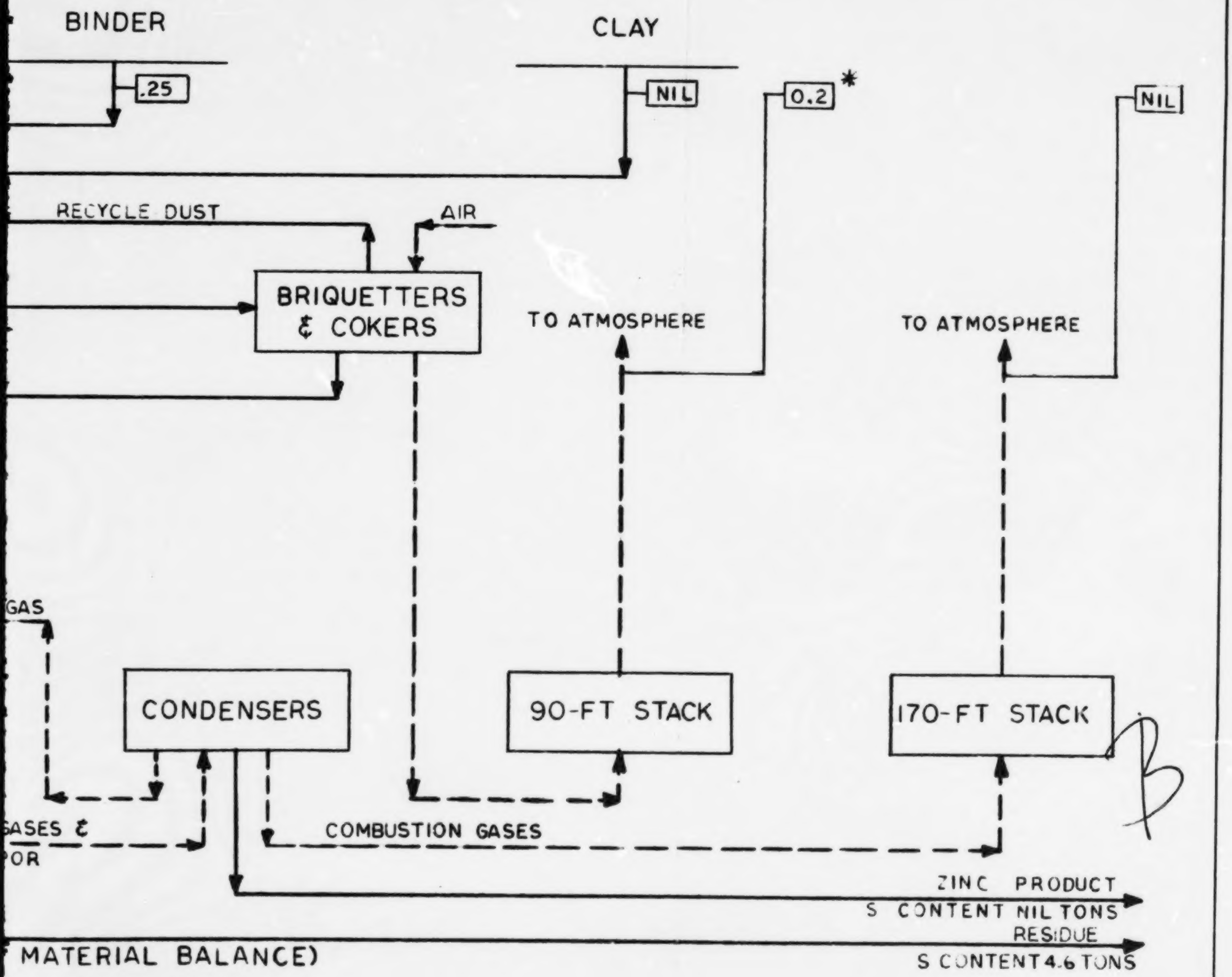
KEY:

N.R.-NOT REPORTED (QUANTITY UNKNOWN)
NIL-NEGLECTED (INSIGNIFICANT QUANTITY NOT AFFECTING MATERIAL BALANCE)
NEG.-NEGLECTED (MINOR QUANTITY PRESENT BUT NOT REPORTED OR ESTIMATED)
SOLIDS & LIQUIDS ——
GASES – – –
SCFM MEASURED AT 32°F AND ONE ATMOSPHERE
*ESTIMATED QUANTITY

BASIS:

TONNAGES ARE
FOR A 24-HOUR
IN SHORT TONS

S-SULFUR


BINDER
.25
CLAY
NIL
0.2 *
NIL
RECYCLE DUST
AIR
BRIQUETTERS & COKERS
TO ATMOSPHERE
TO ATMOSPHERE
GAS
CONDENSERS
90-FT STACK
170-FT STACK
B
GASES &
POR
COMBUSTION GASES
ZINC PRODUCT
S CONTENT NIL TONS
RESIDUE
S CONTENT 4.6 TONS

MATERIAL BALANCE)

BASIS:

TONNAGES ARE GIVEN
FOR A 24-HOUR PERIOD
IN SHORT TONS

S-SULFUR

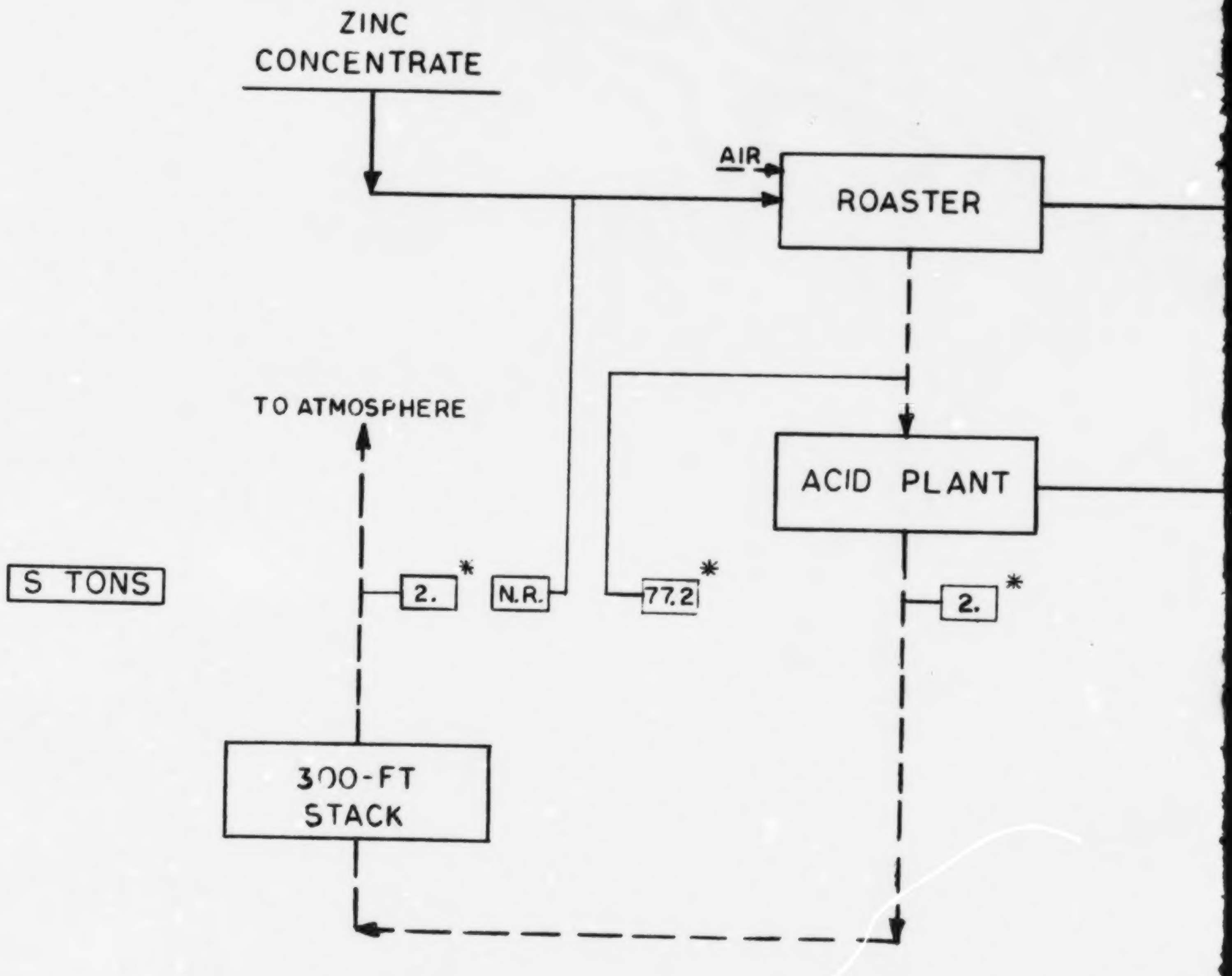
CLIENT
NATIONAL AIR
POLLUTION CONTROL
ADMINISTRATION

TITLE
326.37
ZINC PLANT
FLOW DIAGRAM

ARTHUR G. McKEE & COMPANY
WESTERN KNAPP ENGINEERING DIVISION
SAN FRANCISCO CALIFORNIA

ENG. DEPT. DWG. 10-01-34

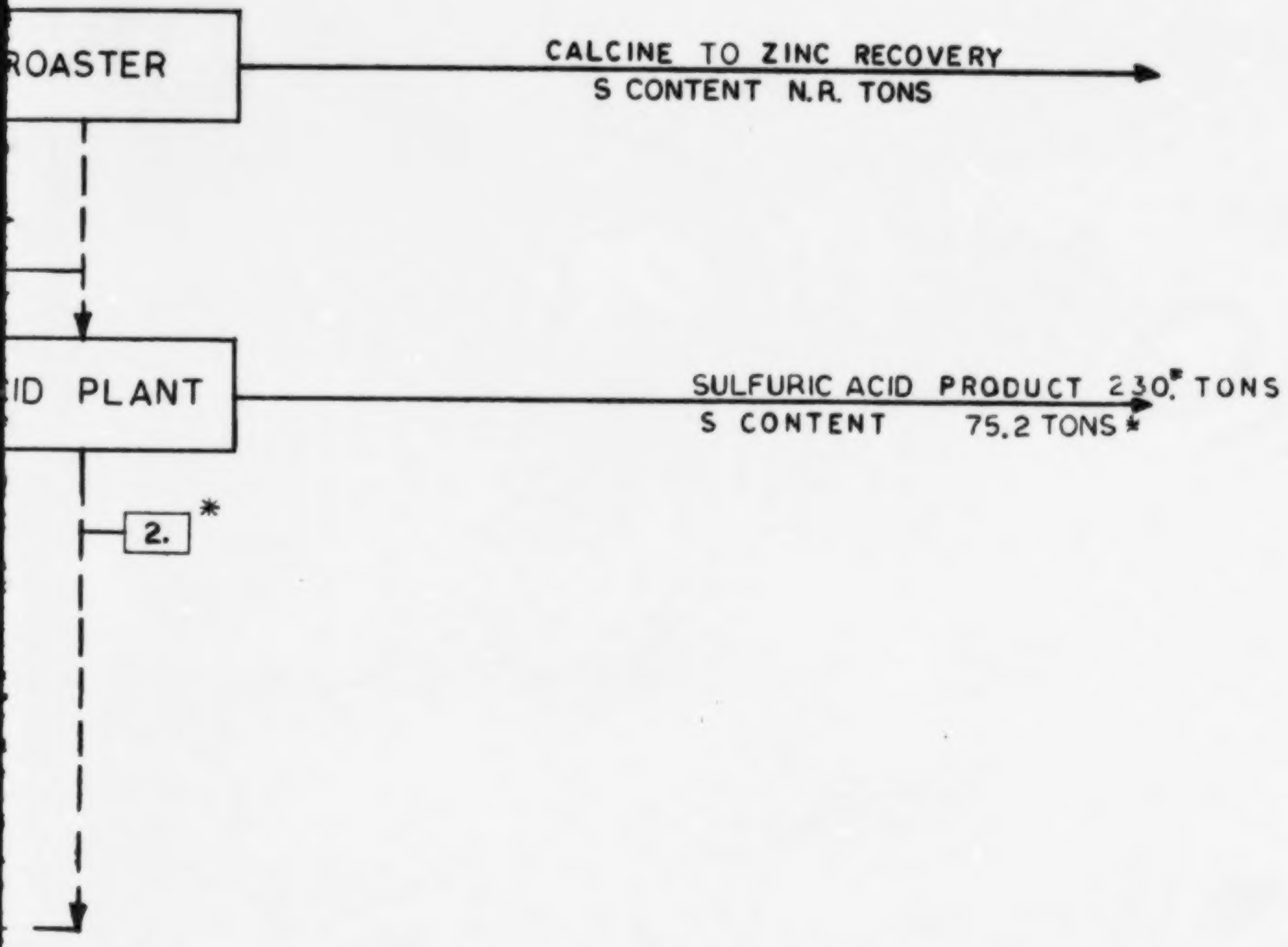
PLATE NO. A-34


ZINC CONCENTRATE
AIR
ROASTER
TO ATMOSPHERE
ACID PLANT
S TONS
2. *
N.R.
77.2 *
2. *
300-FT STACK

BASIS:
TONNAGES ARE GIVEN
FOR A 24-HOUR PERIOD
IN SHORT TONS

S-SULFUR

KEY
*ESTIMATED QUAN
N.R.-NOT REPORTED
SOLIDS & LIQUIDS —
GASES —
SCFM MEASURED AT
AND ONE ATMOSPH


ROASTER
CALCINE TO ZINC RECOVERY
S CONTENT N.R. TONS
ID PLANT
SULFURIC ACID PRODUCT 230.* TONS
S CONTENT 75.2 TONS *
2. *

B

KEY
*ESTIMATED QUANTITY
N.R.-NOT REPORTED (QUANTITY UNKNOWN)
SOLIDS & LIQUIDS ————
GASES — — —
SCFM MEASURED AT 32° F
AND ONE ATMOSPHERE

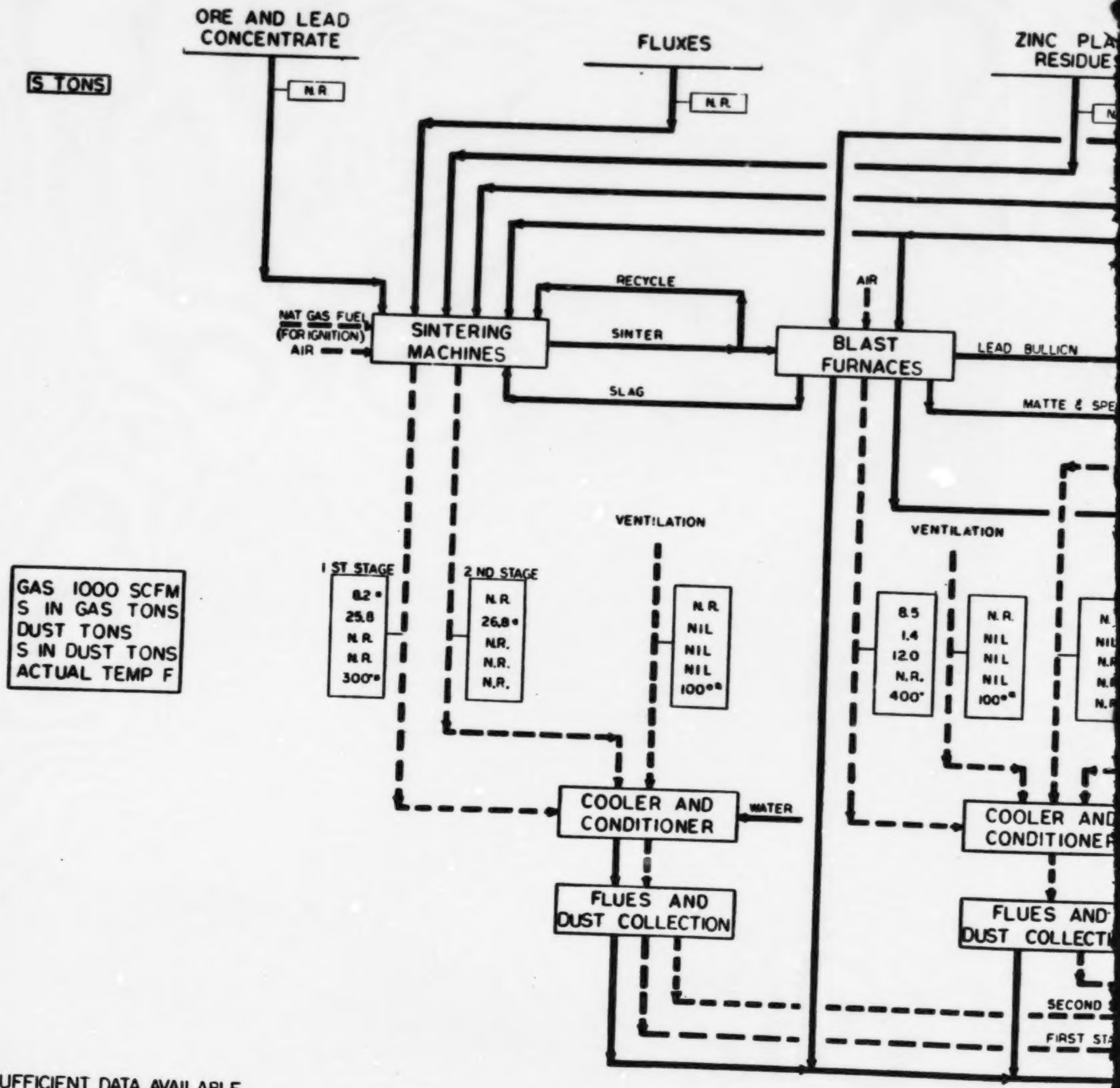
CLIENT
NATIONAL AIR
POLLUTION CONTROL
ADMINISTRATION

ARTHUR G. McKEE & COMPANY
WESTERN KNAPP ENGINEERING DIVISION
SAN FRANCISCO CALIFORNIA

TITLE
326.38
ZINC PLANT
FLOW DIAGRAM

ENG. DEPT. DWG. 10-01-048

PLATE NO. A-35

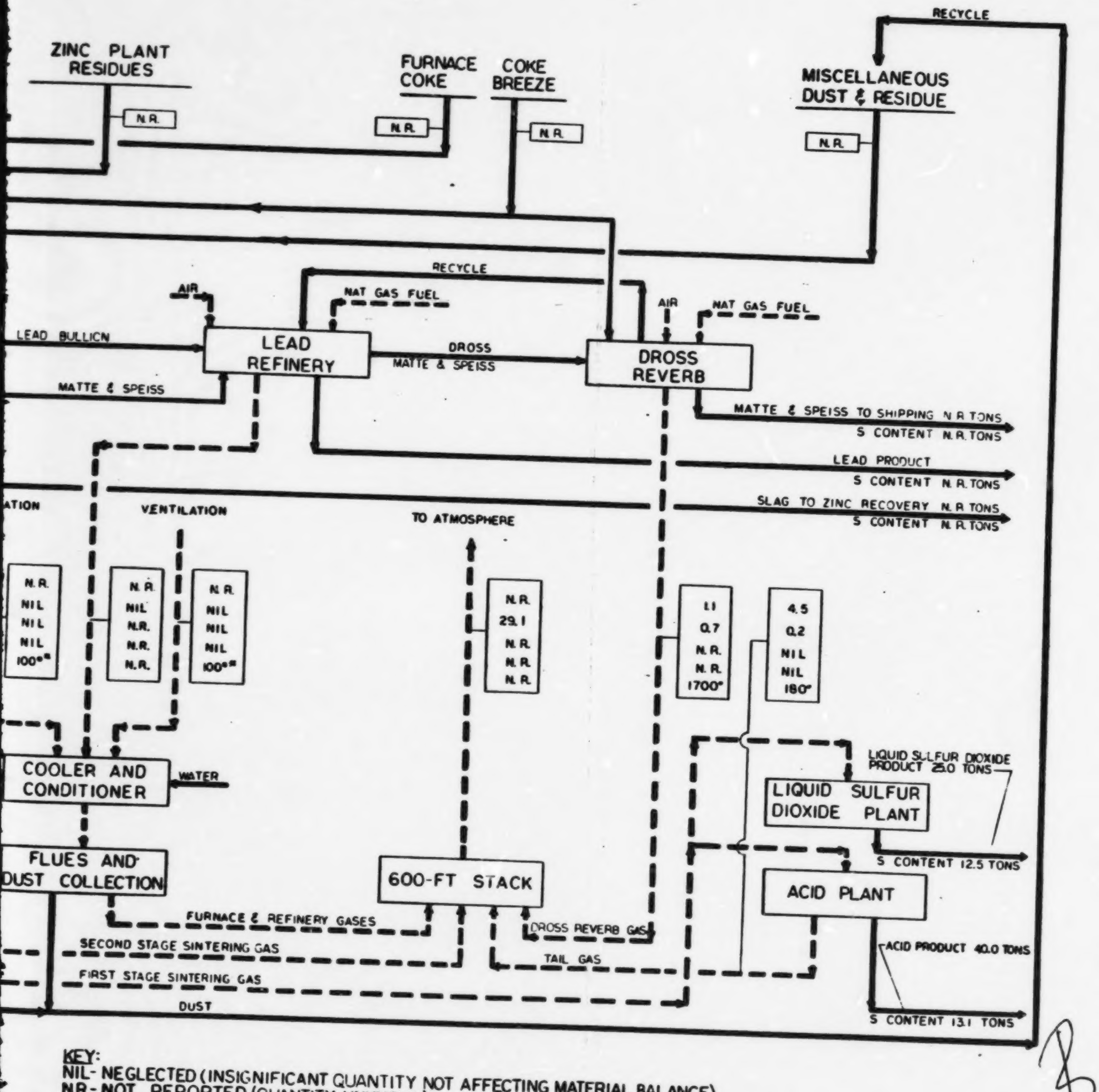

S TONS
ORE AND LEAD CONCENTRATE
N.R.
FLUXES
N.R.
ZINC PLA
RESIDUES
NAT GAS FUEL (FOR IGNITION)
AIR
SINTERING MACHINES
RECYCLE
SINTER
SLAG
AIR
BLAST FURNACES
LEAD BULLION
MATTE & SPE
GAS 1000 SCFM
S IN GAS TONS
DUST TONS
S IN DUST TONS
ACTUAL TEMP F
1 ST STAGE
8.2*
25.8
N.R.
N.R.
300°*
2 ND STAGE
N.R.
26.8*
N.R.
N.R.
N.R.
VENTILATION
N.R.
NIL
NIL
NIL
100°*
8.5
1.4
12.0
N.R.
400°
VENTILATION
N.R.
NIL
NIL
NIL
100°*
COOLER AND CONDITIONER
WATER
FLUES AND DUST COLLECTION
COOLER AND
CONDITIONER
FLUES AND
DUST COLLECTI
SECOND S
FIRST STA

INSUFFICIENT DATA AVAILABLE
TO SHOW COMPLETE SULFUR
BALANCE

BASIS:
TONNAGES ARE GIVEN
FOR A 24-HOUR PERIOD
IN SHORT TONS

S-SULFUR

KEY:
NIL- NEGL
NR- NOT
SOLIDS &
GASES
SCFM ME
AND ONE
* - ESTI


RECYCLE
ZINC PLANT RESIDUES
N.R.
FURNACE COKE
N.R.
COKE BREEZE
N.R.
MISCELLANEOUS DUST & RESIDUE
N.R.
RECYCLE
AIR
NAT GAS FUEL
LEAD BULLION
LEAD REFINERY
MATTE & SPEISS
DROSS
MATTE & SPEISS
AIR
NAT GAS FUEL
DROSS REVERB
MATTE & SPEISS TO SHIPPING N.R. TONS
S CONTENT N.R. TONS
LEAD PRODUCT
S CONTENT N.R. TONS
SLAG TO ZINC RECOVERY N.R. TONS
S CONTENT N.R. TONS
ATION
VENTILATION
TO ATMOSPHERE
N.R.
NIL
NIL
NIL
100°*
N.R.
NIL
N.R.
N.R.
N.R.
N.R.
NIL
NIL
NIL
100°*
N.R.
29.1
N.R.
N.R.
N.R.
1.1
0.7
N.R.
N.R.
1700°
4.5
0.2
NIL
NIL
180°
COOLER AND CONDITIONER
WATER
LIQUID SULFUR DIOXIDE PRODUCT 25.0 TONS
LIQUID SULFUR DIOXIDE PLANT
FLUES AND DUST COLLECTION
600-FT STACK
S CONTENT 12.5 TONS
ACID PLANT
FURNACE & REFINERY GASES
DROSS REVERB GAS
SECOND STAGE SINTERING GAS
TAIL GAS
ACID PRODUCT 40.0 TONS
FIRST STAGE SINTERING GAS
DUST
S CONTENT 13.1 TONS

KEY:
NIL - NEGLECTED (INSIGNIFICANT QUANTITY NOT AFFECTING MATERIAL BALANCE)
N.R. - NOT REPORTED (QUANTITY UNKNOWN)
SOLIDS & LIQUIDS ———
GASES – – –
SCFM MEASURED AT 32°F
AND ONE ATMOSPHERE
* - ESTIMATED QUANTITY

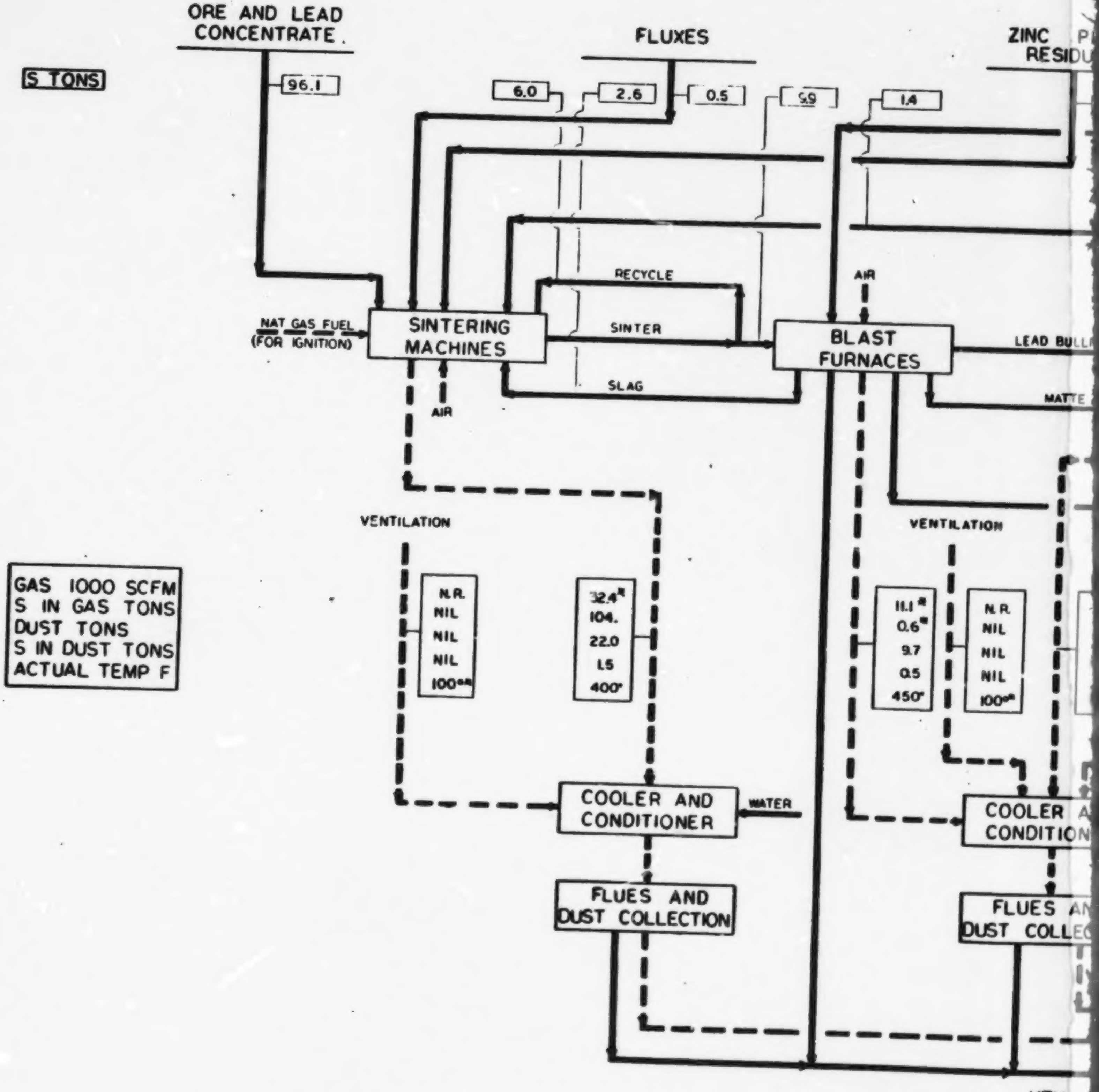
CLIENT
NATIONAL AIR
POLLUTION CONTROL
ADMINISTRATION

TITLE
326.09
LEAD PLANT
FLOW DIAGRAM

ARTHUR G. McKEE & COMPANY
WESTERN KNAPP ENGINEERING DIVISION
SAN FRANCISCO CALIFORNIA

ENG. DEPT. DWG. 10-01-010

PLATE NO. A-36


S TONS
ORE AND LEAD CONCENTRATE
96.1
FLUXES
6.0
2.6
0.5
5.9
1.4
ZINC
RESIDU
NAT GAS FUEL (FOR IGNITION)
SINTERING MACHINES
RECYCLE
SINTER
SLAG
AIR
BLAST FURNACES
LEAD BULL
MATTE
VENTILATION
N.R.
NIL
NIL
NIL
100°R
32.4*
104.
22.0
1.5
400°
11.1*
0.6*
9.7
0.5
450°
N.R.
NIL
NIL
NIL
100°R
GAS 1000 SCFM
S IN GAS TONS
DUST TONS
S IN DUST TONS
ACTUAL TEMP F
COOLER AND CONDITIONER
WATER
FLUES AND DUST COLLECTION
COOLER A
CONDITION
FLUES AN
DUST COLLE

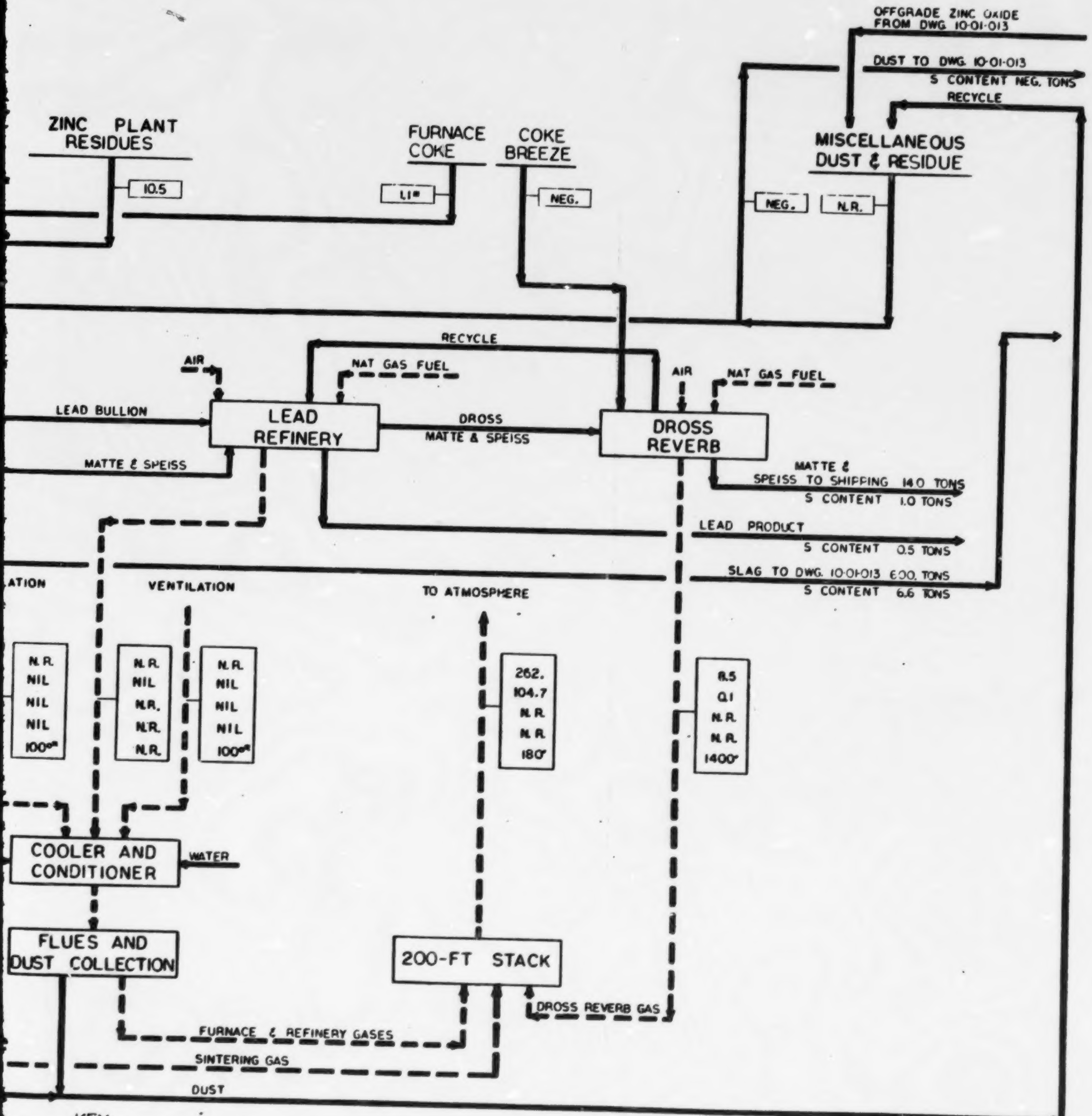
BASIS:

TONNAGES ARE GIVEN
FOR A 24-HOUR PERIOD
IN SHORT TONS

S-SULFUR

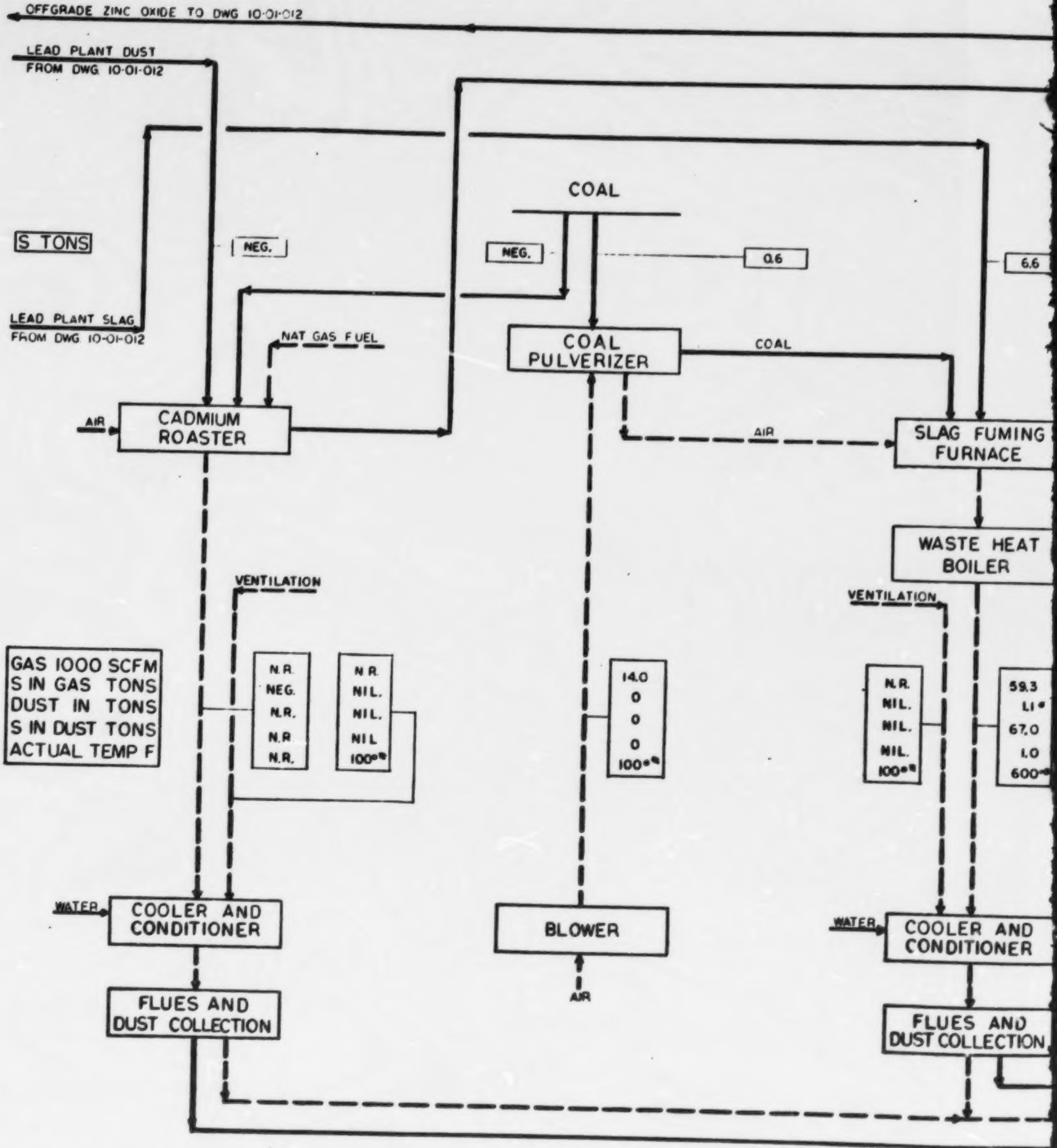
KEY:
NIL-NE
NEG:NE
NR-NO
SOLIDS
GASES
SCFM
AND O
*- ES

A


OFFGRADE ZINC OXIDE FROM DWG. 10-01-013
DUST TO DWG. 10-01-013
S CONTENT NEG. TONS
RECYCLE
ZINC PLANT RESIDUES
10.5
FURNACE COKE
1.1*
COKE BREEZE
NEG.
MISCELLANEOUS DUST & RESIDUE
NEG.
N.R.
RECYCLE
AIR
NAT GAS FUEL
LEAD BULLION
LEAD REFINERY
DROSS
MATTE & SPEISS
MATTE & SPEISS
AIR
NAT GAS FUEL
DROSS REVERB
MATTE & SPEISS TO SHIPPING 14.0 TONS
S CONTENT 1.0 TONS
LEAD PRODUCT
S CONTENT 0.5 TONS
SLAG TO DWG. 10-01-013 600. TONS
S CONTENT 6.6 TONS
ATION
VENTILATION
TO ATMOSPHERE
N.R. NIL NIL NIL 100*F
N.R. NIL N.R. N.R. N.R.
N.R. NIL NIL NIL 100*F
262. 104.7 N.R. N.R. 180°
8.5 0.1 N.R. N.R. 1400°
COOLER AND CONDITIONER
WATER
FLUES AND DUST COLLECTION
200-FT STACK
DROSS REVERB GAS
FURNACE & REFINERY GASES
SINTERING GAS
DUST

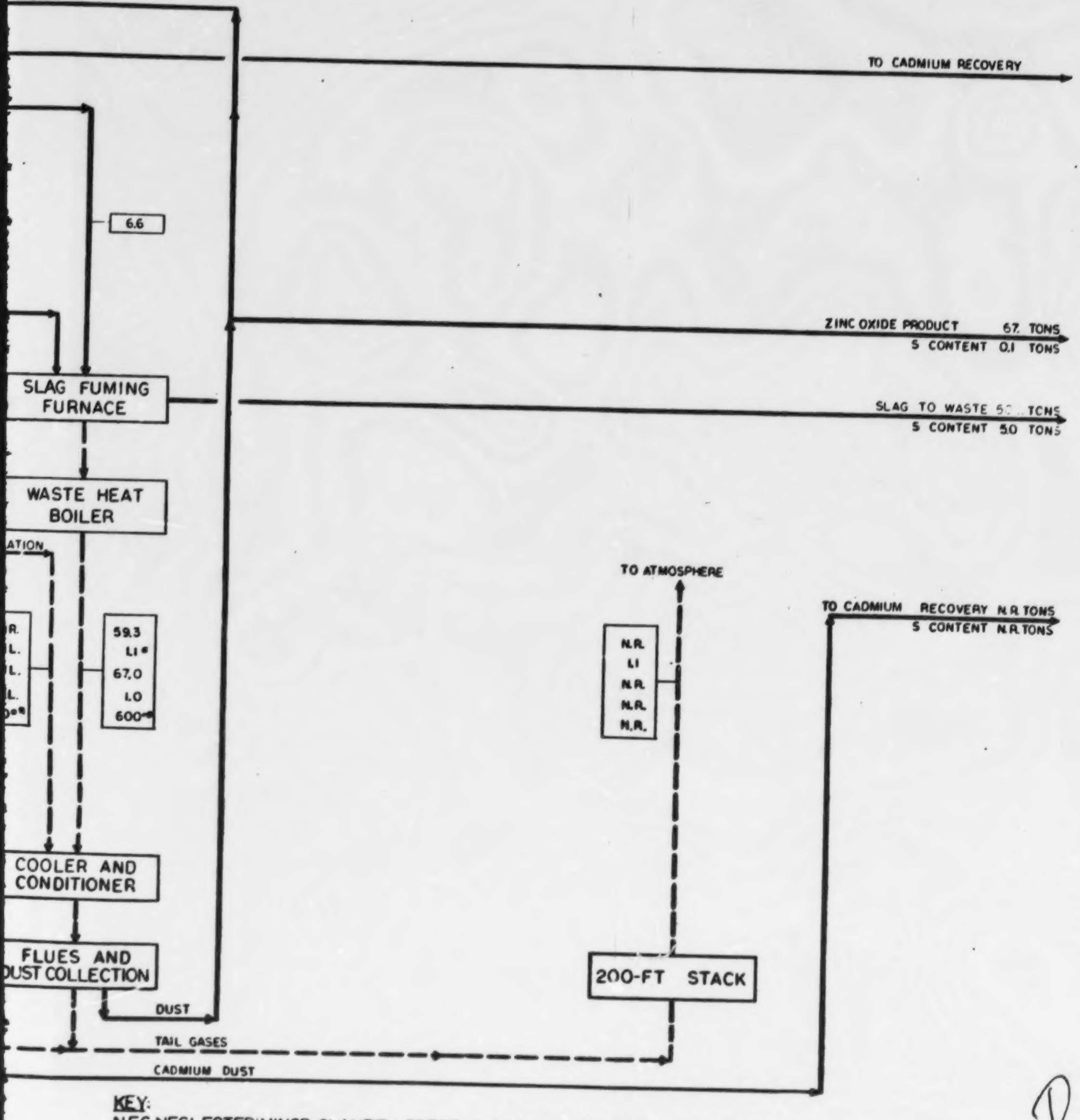
KEY:
NIL-NEGLECTED (INSIGNIFICANT QUANTITY NOT AFFECTING MATERIAL BALANCE)
NEG-NEGLECTED (MINOR QUANTITY PRESENT, BUT NOT REPORTED OR ESTIMATED)
NR-NOT REPORTED (QUANTITY UNKNOWN)
SOLIDS & LIQUIDS ▬▬▬
GASES ▬ ▬ ▬
SCFM MEASURED AT 32°F
AND ONE ATMOSPHERE
* - ESTIMATED QUANTITY

CLIENT	
NATIONAL AIR POLLUTION CONTROL ADMINISTRATION	ARTHUR G. McKEE & COMPANY WESTERN KNAPP ENGINEERING DIVISION SAN FRANCISCO CALIFORNIA
TITLE 32610 LEAD PLANT FLOW DIAGRAM	ENG. DEPT. DWG. 10-01-012 **PLATE NO. A-37**


OFFGRADE ZINC OXIDE TO DWG 10-01-012
LEAD PLANT DUST
FROM DWG 10-01-012
S TONS
NEG.
LEAD PLANT SLAG
FROM DWG 10-01-012
COAL
NEG.
0.6
6.6
NAT GAS FUEL
COAL PULVERIZER
COAL
AIR
CADMIUM ROASTER
AIR
SLAG FUMING FURNACE
WASTE HEAT BOILER
VENTILATION
VENTILATION
GAS 1000 SCFM
S IN GAS TONS
DUST IN TONS
S IN DUST TONS
ACTUAL TEMP F
N.R.
NEG.
N.R.
N.R.
N.R.
N.R.
NIL.
NIL.
NIL
100°F
14.0
0
0
0
100°F
N.R.
NIL.
NIL.
NIL.
100°F
59.3
1.1*
67.0
1.0
600°
WATER
COOLER AND CONDITIONER
BLOWER
AIR
WATER
COOLER AND CONDITIONER
FLUES AND DUST COLLECTION
FLUES AND DUST COLLECTION

BASIS:
TONNAGES ARE GIVEN
FOR A 24-HOUR PERIOD
IN SHORT TONS

KEY:
NEG.
NIL -
N.R. -
SOLI
GASE
SCFM
AND
* -


TO CADMIUM RECOVERY
6.6
ZINC OXIDE PRODUCT 67. TONS
S CONTENT 0.1 TONS
SLAG FUMING FURNACE
SLAG TO WASTE 50. TONS
S CONTENT 5.0 TONS
WASTE HEAT BOILER
ATION
R.
L.
L.
L.
0*
59.3
LI*
67.0
1.0
600*
TO ATMOSPHERE
N.R.
LI
N.R.
N.R.
N.R.
TO CADMIUM RECOVERY N.R. TONS
S CONTENT N.R. TONS
COOLER AND CONDITIONER
FLUES AND DUST COLLECTION
200-FT STACK
DUST
TAIL GASES
CADMIUM DUST

KEY:
NEG-NEGLECTED (MINOR QUANTITY PRESENT, BUT NOT REPORTED OR ESTIMATED)
NIL -NEGLECTED (INSIGNIFICANT QUANTITY NOT AFFECTING MATERIAL BALANCE)
N.R.-NOT REPORTED (QUANTITY UNKNOWN)
SOLIDS & LIQUIDS ———
GASES – – – –
SCFM MEASURED AT 32° F
AND ONE ATMOSPHERE
* -ESTIMATED QUANTITY

B

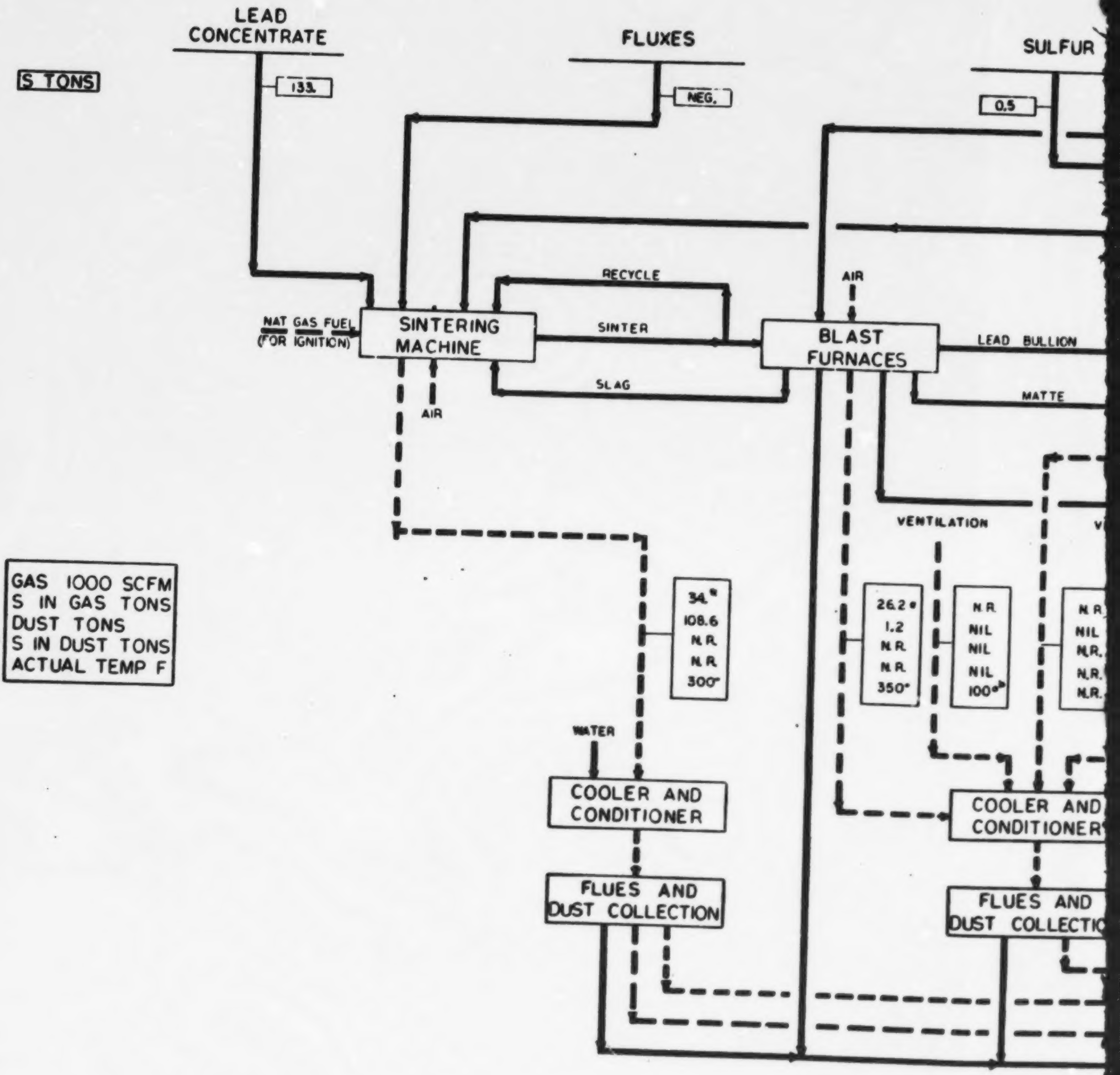
NATIONAL AIR
POLLUTION CONTROL
ADMINISTRATION

326.10
LEAD PLANT BYPRODUCTS
FLOW DIAGRAM

ARTHUR G. McKEE & COMPANY
WESTERN KNAPP ENGINEERING DIVISION
SAN FRANCISCO CALIFORNIA

ENG. DEPT. DWG. 10-01-013

PLATE NO. A38


S TONS
LEAD CONCENTRATE
133.
FLUXES
NEG.
SULFUR
0.5
NAT GAS FUEL (FOR IGNITION)
SINTERING MACHINE
AIR
RECYCLE
SINTER
SLAG
AIR
BLAST FURNACES
LEAD BULLION
MATTE
VENTILATION
V
GAS 1000 SCFM
S IN GAS TONS
DUST TONS
S IN DUST TONS
ACTUAL TEMP F
34.*
108.6
N.R.
N.R.
300°
26.2*
1.2
N.R.
N.R.
350°
N.R.
NIL
NIL
NIL
100*
N.R.
NIL
N.R.
N.R.
N.R.
WATER
COOLER AND CONDITIONER
FLUES AND DUST COLLECTION
COOLER AND CONDITIONER
FLUES AND DUST COLLECTI

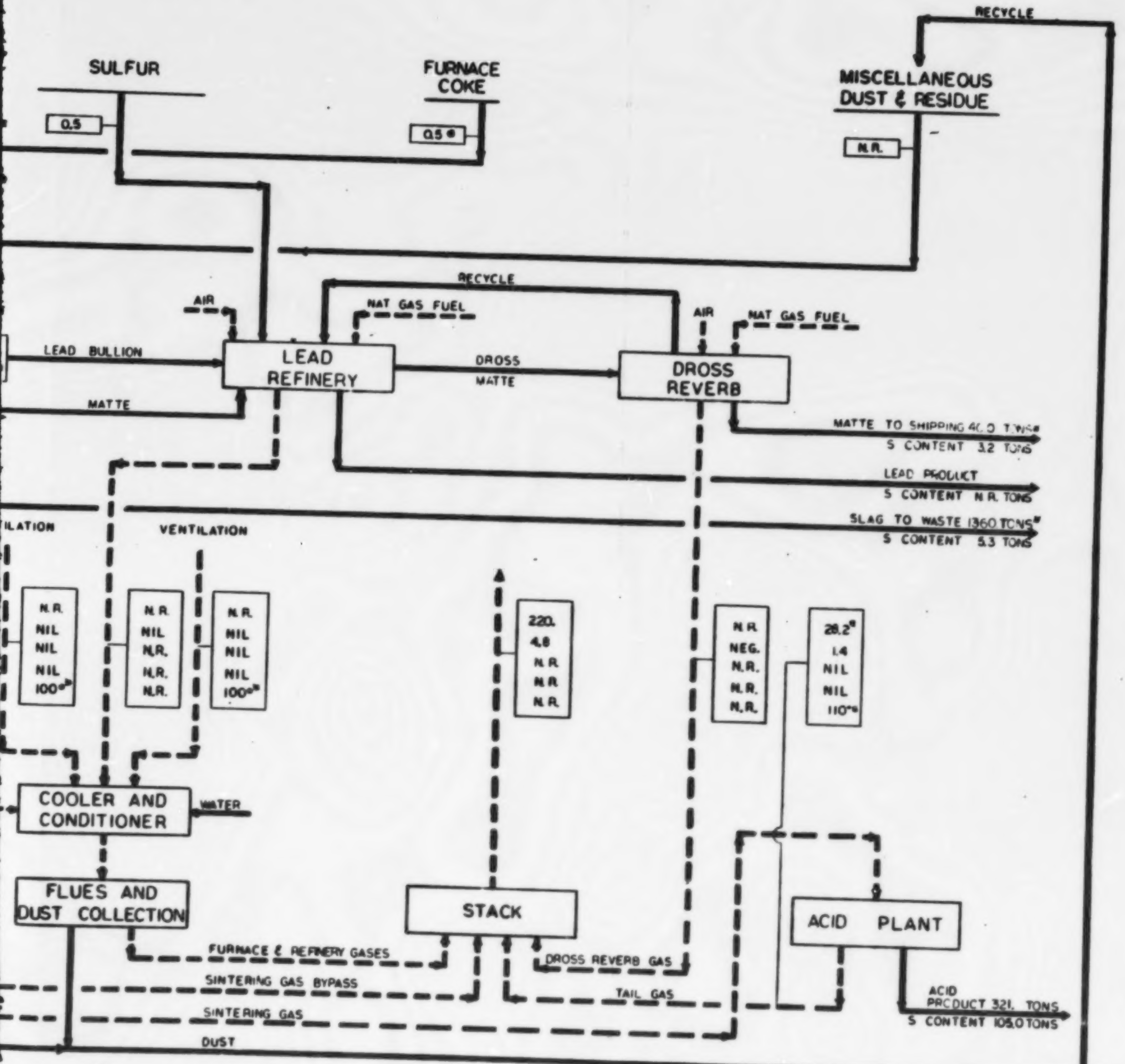
BASIS:

TONNAGES ARE GIVEN
FOR A 24-HOUR PERIOD
IN SHORT TONS

S-SULFUR

KEY:
NIL- NEGL
NEG.-NEGL
N.R.- NOT
SOLIDS &
GASES
SCFM MEA
AND ONE
* - ESTIM

A


SULFUR
0.5
FURNACE COKE
0.5*
MISCELLANEOUS DUST & RESIDUE
N.R.
RECYCLE
RECYCLE
AIR
NAT GAS FUEL
AIR
NAT GAS FUEL
LEAD BULLION
LEAD REFINERY
DROSS
MATTE
DROSS REVERB
MATTE
MATTE TO SHIPPING 40.0 TONS*
S CONTENT 3.2 TONS
LEAD PRODUCT
S CONTENT N.R. TONS
SLAG TO WASTE 1360 TONS*
S CONTENT 5.3 TONS
ILATION
VENTILATION
N.R.
NIL
NIL
NIL
100°*
N.R.
NIL
N.R.
N.R.
N.R.
N.R.
NIL
NIL
NIL
100°*
220.
4.8
N.R.
N.R.
N.R.
N.R.
NEG.
N.R.
N.R.
N.R.
28.2*
1.4
NIL
NIL
110°*
COOLER AND CONDITIONER
WATER
FLUES AND DUST COLLECTION
STACK
ACID PLANT
FURNACE & REFINERY GASES
DROSS REVERB GAS
SINTERING GAS BYPASS
TAIL GAS
SINTERING GAS
DUST
ACID PRODUCT 321. TONS
S CONTENT 105.0 TONS

KEY:
NIL- NEGLECTED (INSIGNIFICANT QUANTITY NOT AFFECTING MATERIAL BALANCE)
NEG: NEGLECTED (MINOR QUANTITY PRESENT BUT NOT REPORTED OR ESTIMATED)
N.R.- NOT REPORTED (QUANTITY UNKNOWN)
SOLIDS & LIQUIDS ▬▬
GASES ▬ ▬ ▬
SCFM MEASURED AT 32°F
AND ONE ATMOSPHERE
* - ESTIMATED QUANTITY

B

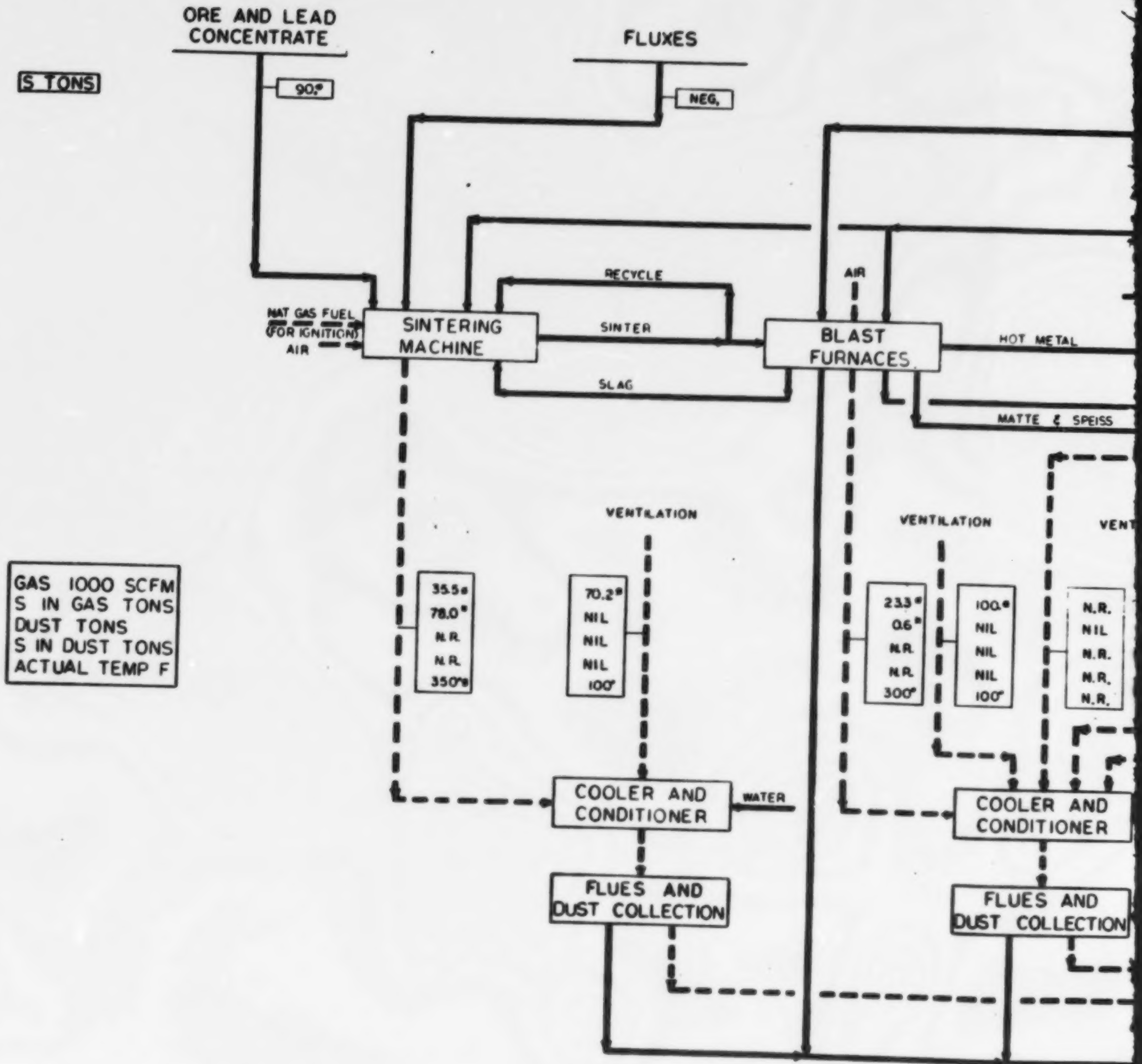
NATIONAL AIR
POLLUTION CONTROL
ADMINISTRATION

32617
LEAD PLANT
FLOW DIAGRAM

ARTHUR G. McKEE & COMPANY
WESTERN KNAPP ENGINEERING DIVISION
SAN FRANCISCO CALIFORNIA

ENG. DEPT. DWG. 10-01-021

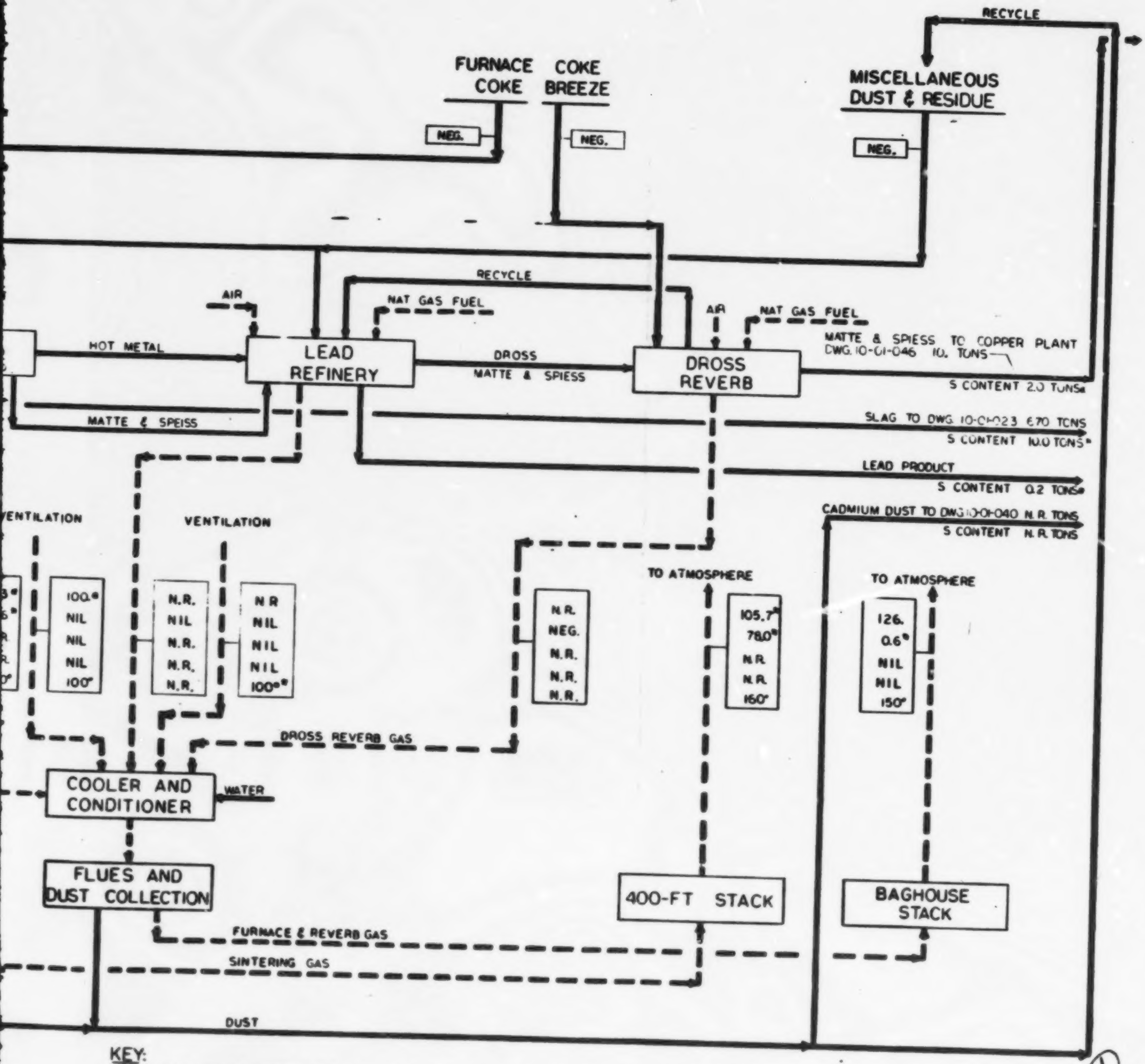
PLATE NO. A39


ORE AND LEAD CONCENTRATE
FLUXES
S TONS
90.*
NEG.
RECYCLE
AIR
NAT GAS FUEL (FOR IGNITION)
AIR
SINTERING MACHINE
SINTER
BLAST FURNACES
HOT METAL
SLAG
MATTE & SPEISS
VENTILATION
VENTILATION
VENT
GAS 1000 SCFM
S IN GAS TONS
DUST TONS
S IN DUST TONS
ACTUAL TEMP F
35.5*
78.0*
N.R.
N.R.
350°*
70.2*
NIL
NIL
NIL
100°
23.3*
0.6*
N.R.
N.R.
300°
100.*
NIL
NIL
NIL
100°
N.R.
NIL
N.R.
N.R.
N.R.
COOLER AND CONDITIONER
WATER
COOLER AND CONDITIONER
FLUES AND DUST COLLECTION
FLUES AND DUST COLLECTION

BASIS:
TONNAGES ARE GIVEN
FOR A 24-HOUR PERIOD
IN SHORT TONS

S-SULFUR

KEY:
NIL-NEGLEC
NEG:NEGLEC
N.R.-NOT R
SOLIDS & LI
GASES
SCFM MEAS
AND ONE A
* - ESTIMAT

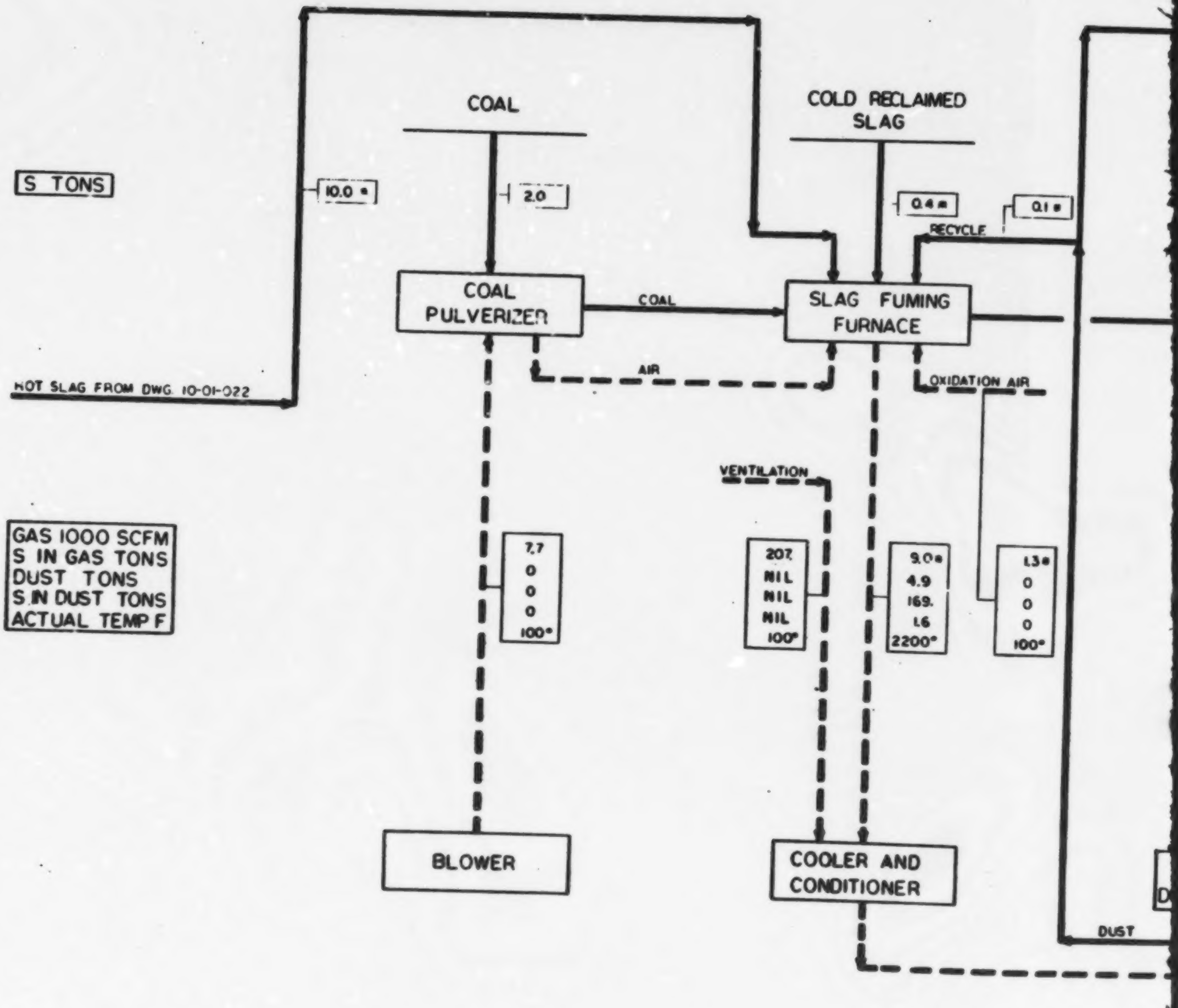

FURNACE COKE
COKE BREEZE
NEG.
NEG.
MISCELLANEOUS DUST & RESIDUE
NEG.
RECYCLE
RECYCLE
AIR
NAT GAS FUEL
HOT METAL
LEAD REFINERY
DROSS
MATTE & SPEISS
AIR
NAT GAS FUEL
DROSS REVERB
MATTE & SPEISS TO COPPER PLANT DWG.10-01-046 10. TONS
S CONTENT 2.0 TONS*
MATTE & SPEISS
SLAG TO DWG 10-01-023 670 TONS
S CONTENT 10.0 TONS*
LEAD PRODUCT
S CONTENT 0.2 TONS*
CADMIUM DUST TO DWG10-01-040 N.R. TONS
S CONTENT N.R. TONS
VENTILATION
VENTILATION
100.* NIL NIL NIL 100°
N.R. NIL N.R. N.R. N.R.
N R NIL NIL NIL 100°*
N.R. NEG. N.R. N.R. N.R.
TO ATMOSPHERE
105.7* 78.0* N.R. N.R. 160°
TO ATMOSPHERE
126. 0.6* NIL NIL 150°
DROSS REVERB GAS
COOLER AND CONDITIONER
WATER
FLUES AND DUST COLLECTION
400-FT STACK
BAGHOUSE STACK
FURNACE & REVERB GAS
SINTERING GAS
DUST

KEY:

NIL - NEGLECTED (INSIGNIFICANT QUANTITY NOT AFFECTING MATERIAL BALANCE)
NEG: NEGLECTED (MINOR QUANTITY PRESENT, BUT NOT AFFECTING MATERIAL BALANCE)
N.R. - NOT REPORTED (QUANTITY UNKNOWN, BUT NOT REPORTED OR ESTIMATED)
SOLIDS & LIQUIDS ▬▬
GASES ▬ ▬
SCFM MEASURED AT 32°F
AND ONE ATMOSPHERE
* - ESTIMATED QUANTITY

B

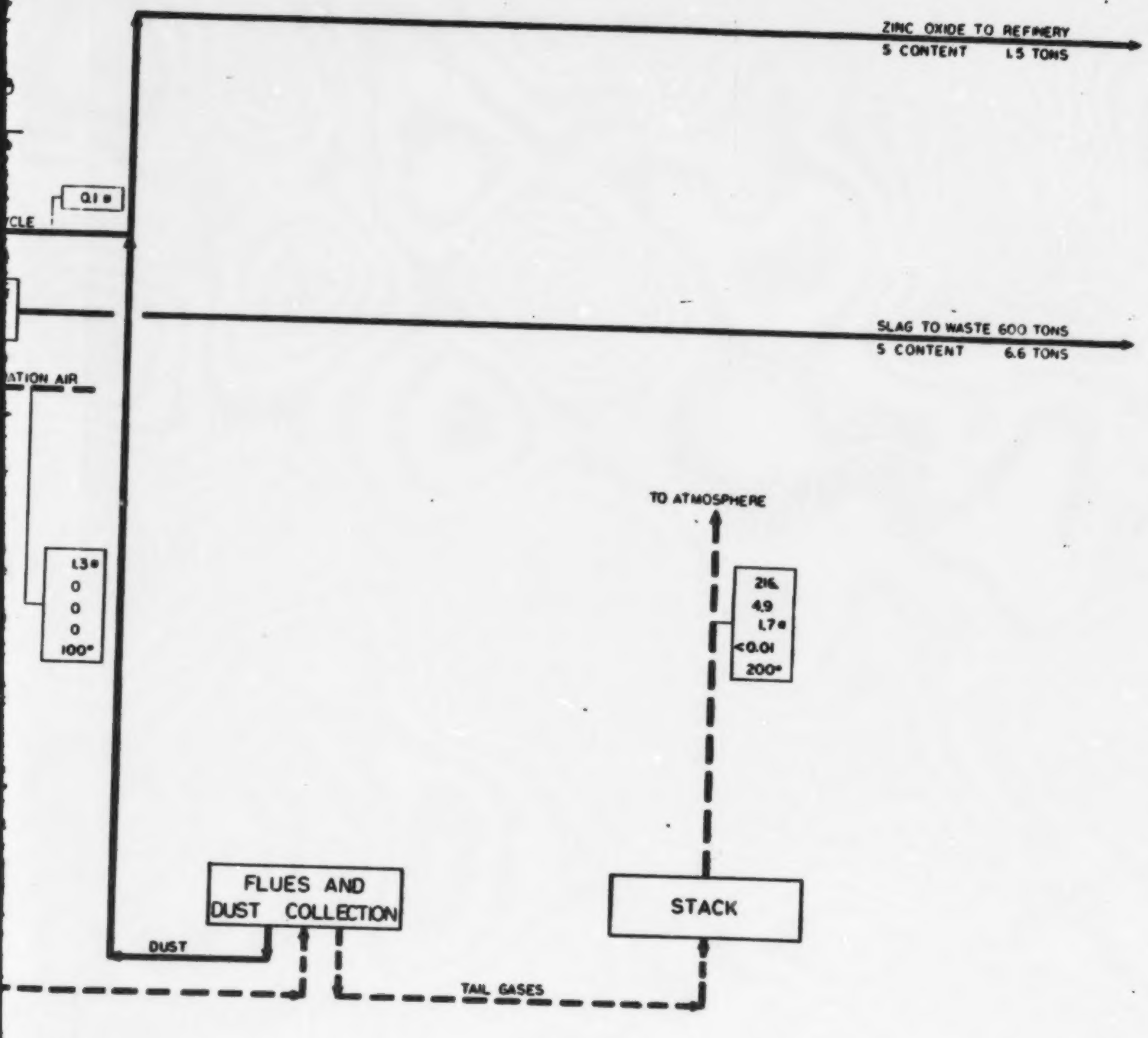
NATIONAL AIR POLLUTION CONTROL ADMINISTRATION	ARTHUR G. McKEE & COMPANY WESTERN KNAPP ENGINEERING DIVISION SAN FRANCISCO CALIFORNIA
3261.8 LEAD PLANT FLOW DIAGRAM	ENG. DEPT. DWG. 10-01-022 PLATE NO: A-40


S TONS
COAL
COLD RECLAIMED SLAG
10.0 *
2.0
0.4 *
0.1 *
RECYCLE
COAL PULVERIZER
COAL
SLAG FUMING FURNACE
AIR
HOT SLAG FROM DWG. 10-01-022
OXIDATION AIR
VENTILATION
GAS 1000 SCFM
S IN GAS TONS
DUST TONS
S IN DUST TONS
ACTUAL TEMP F
7.7
0
0
0
100°
207.
NIL
NIL
NIL
100°
9.0 *
4.9
169.
1.6
2200°
1.3 *
0
0
0
100°
BLOWER
COOLER AND CONDITIONER
DUST

BASIS:
TONNAGES ARE GIVEN
FOR A 24 HOUR PERIOD
IN SHORT TONS

S-SULFUR

KEY:
NIL - NEGLEC
SOLIDS & LI
GASES
SCFM MEAS
AND ONE A
* - ESTIMAT


ZINC OXIDE TO REFINERY
S CONTENT 1.5 TONS
0.1 *
YCLE
SLAG TO WASTE 600 TONS
S CONTENT 6.6 TONS
ATION AIR
1.3 *
0
0
0
100°
TO ATMOSPHERE
216.
4.9
1.7 *
<0.01
200°
FLUES AND DUST COLLECTION
STACK
DUST
TAIL GASES

B

KEY:
NIL - NEGLECTED (INSIGNIFICANT QUANTITY NOT AFFECTING MATERIAL BALANCE)
SOLIDS & LIQUIDS ————
GASES – – – –
SCFM MEASURED AT 32° F
AND ONE ATMOSPHERE
* - ESTIMATED QUANTITY

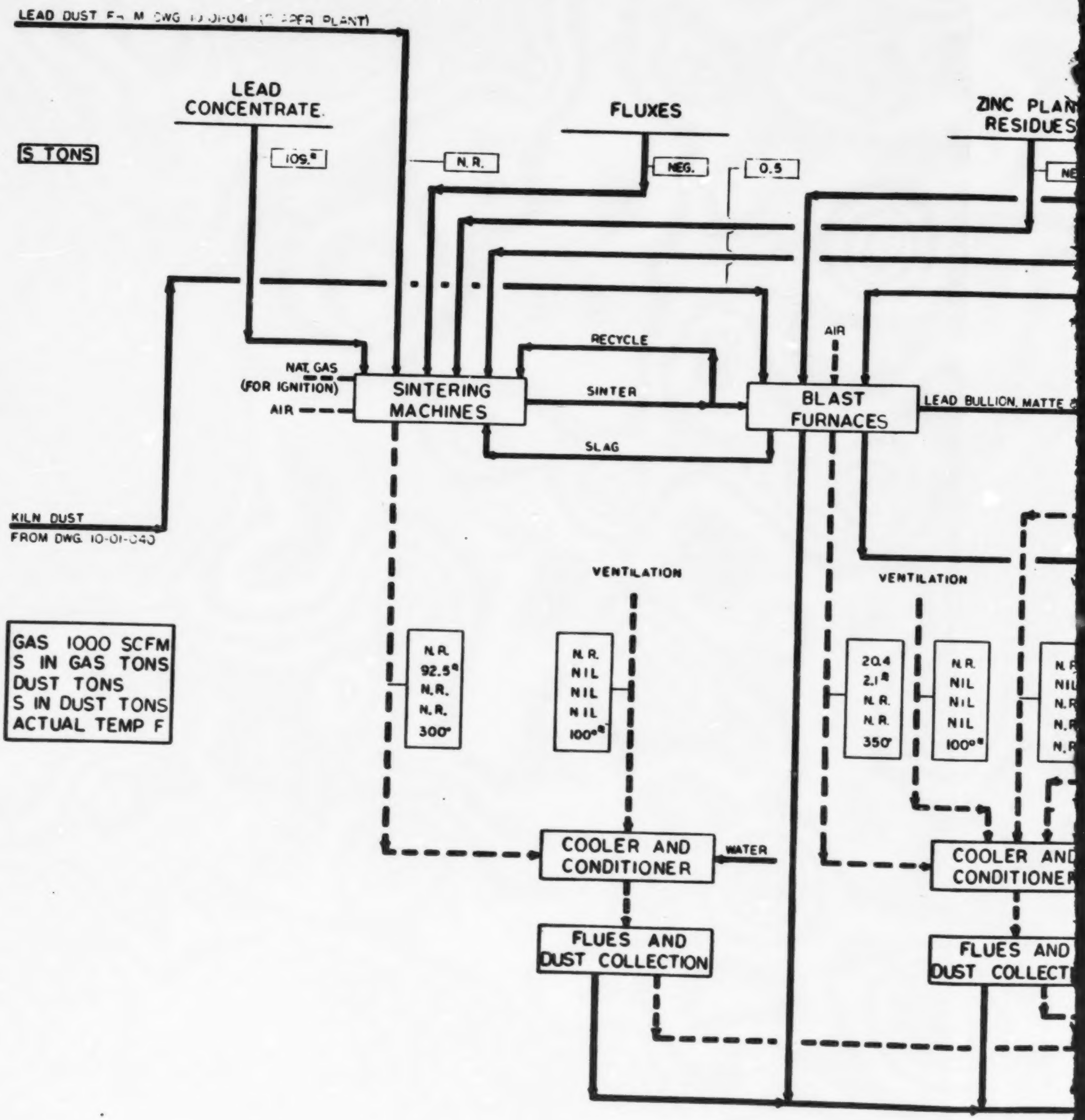
CLIENT
NATIONAL AIR
POLLUTION CONTROL
ADMINISTRATION

ARTHUR G. McKEE & COMPANY
WESTERN KNAPP ENGINEERING DIVISION
SAN FRANCISCO CALIFORNIA

TITLE
326.19
LEAD PLANT BYPRODUCTS
FLOW DIAGRAM

ENG. DEPT. DWG. 10-01-023

PLATE NO. A-41

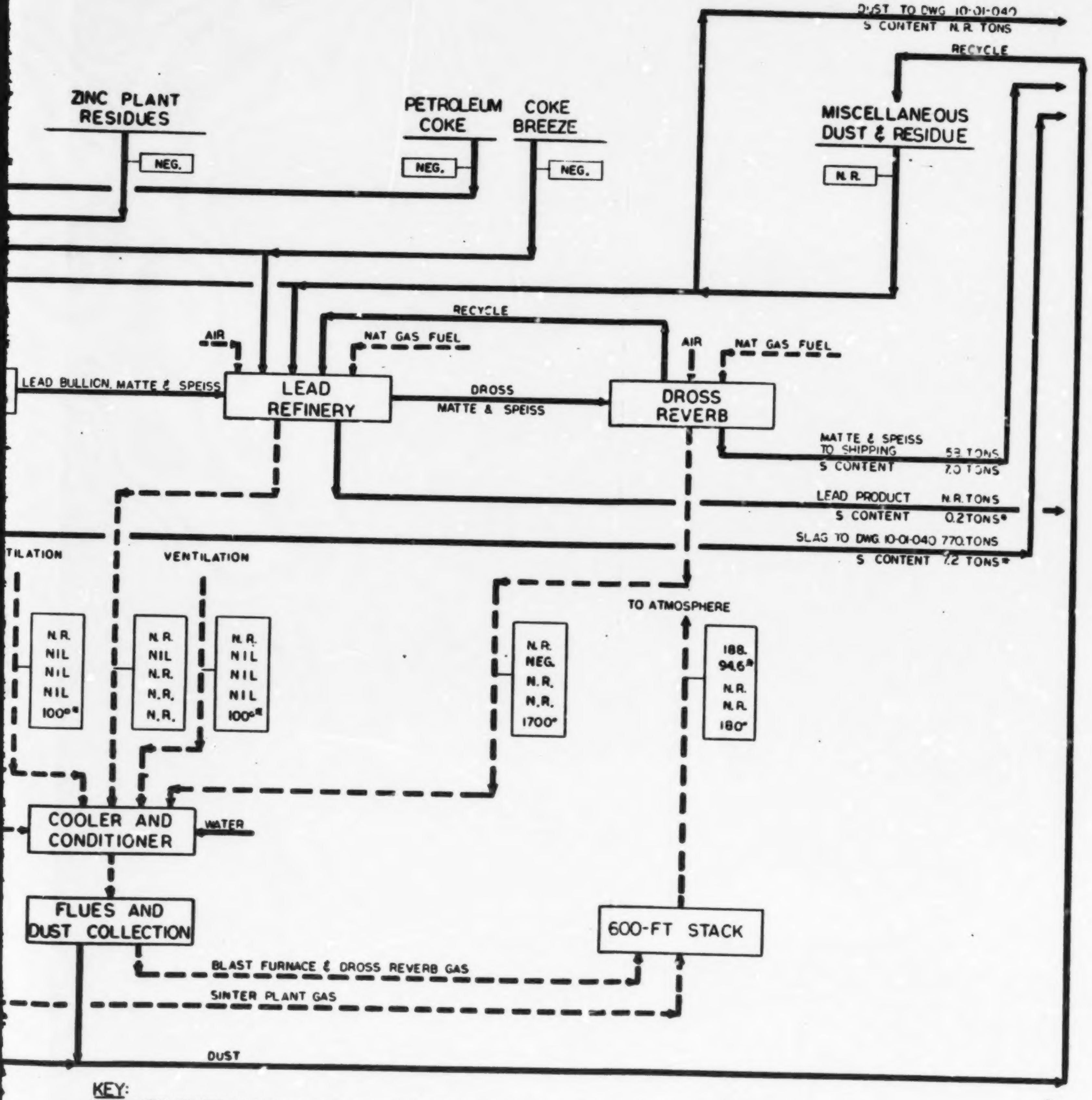

LEAD DUST FROM DWG 10-01-041 (COPPER PLANT)
LEAD CONCENTRATE.
S TONS
109.ª
N.R.
FLUXES
NEG.
0.5
ZINC PLAN
RESIDUES
NE
RECYCLE
AIR
NAT. GAS (FOR IGNITION)
AIR
SINTERING MACHINES
SINTER
SLAG
BLAST FURNACES
LEAD BULLION, MATTE &
KILN DUST FROM DWG. 10-01-040
VENTILATION
VENTILATION
GAS 1000 SCFM
S IN GAS TONS
DUST TONS
S IN DUST TONS
ACTUAL TEMP F
N.R.
92.5ª
N.R.
N.R.
300°
N.R.
NIL
NIL
NIL
100°ª
20.4
2.1ª
N.R.
N.R.
350°
N.R.
NIL
NIL
NIL
100°ª
N.R
NIL
N.R
N.R
N.R
COOLER AND CONDITIONER
WATER
FLUES AND DUST COLLECTION
COOLER AND CONDITIONER
FLUES AND DUST COLLECT

BASIS:

TONNAGES ARE GIVEN
FOR A 24-HOUR PERIOD
IN SHORT TONS

S-SULFUR

KEY:
NEG.-NEG
NIL-NEG
N.R.-NOT
SOLIDS &
GASES
SCFM ME
AND ONE
ª - ESTI


DUST TO DWG 10-01-040
S CONTENT N.R. TONS
RECYCLE
ZINC PLANT RESIDUES
NEG.
PETROLEUM COKE
NEG.
COKE BREEZE
NEG.
MISCELLANEOUS DUST & RESIDUE
N.R.
RECYCLE
AIR
NAT GAS FUEL
AIR
NAT GAS FUEL
LEAD BULLION, MATTE & SPEISS
LEAD REFINERY
DROSS
MATTE & SPEISS
DROSS REVERB
MATTE & SPEISS TO SHIPPING 53 TONS
S CONTENT 7.0 TONS
LEAD PRODUCT N.R. TONS
S CONTENT 0.2 TONS*
SLAG TO DWG 10-01-040 770 TONS
S CONTENT 7.2 TONS*
TILATION
VENTILATION
N.R.
NIL
NIL
NIL
100°*
N.R.
NIL
N.R.
N.R.
N.R.
N.R.
NIL
NIL
NIL
100°*
N.R.
NEG.
N.R.
N.R.
1700°
TO ATMOSPHERE
188
94.6*
N.R.
N.R.
180°
COOLER AND CONDITIONER
WATER
FLUES AND DUST COLLECTION
600-FT STACK
BLAST FURNACE & DROSS REVERB GAS
SINTER PLANT GAS
DUST

KEY:
NEG.-NEGLECTED (MINOR QUANTITY PRESENT, BUT NOT REPORTED OR ESTIMATED)
NIL-NEGLECTED (INSIGNIFICANT QUANTITY NOT AFFECTING MATERIAL BALANCE)
N.R.-NOT REPORTED (QUANTITY UNKNOWN)
SOLIDS & LIQUIDS ━━━
GASES ━ ━ ━
SCFM MEASURED AT 32°F
AND ONE ATMOSPHERE
* - ESTIMATED QUANTITY

B

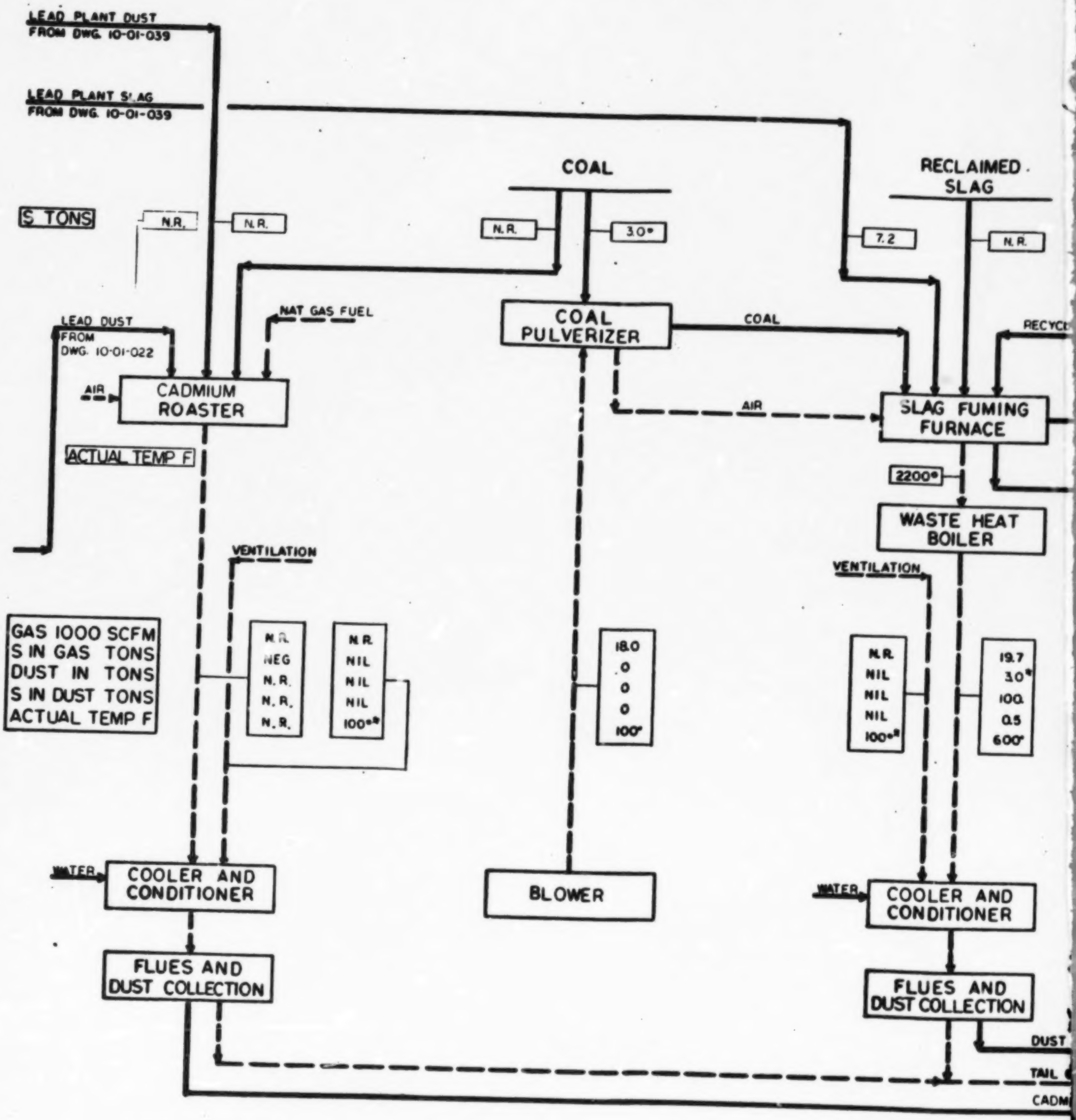
NATIONAL AIR
POLLUTION CONTROL
ADMINISTRATION

326.33
LEAD PLANT
FLOW DIAGRAM

ARTHUR G. McKEE & COMPANY
WESTERN KNAPP ENGINEERING DIVISION
SAN FRANCISCO CALIFORNIA

ENG. DEPT. DWG. 10-01-039

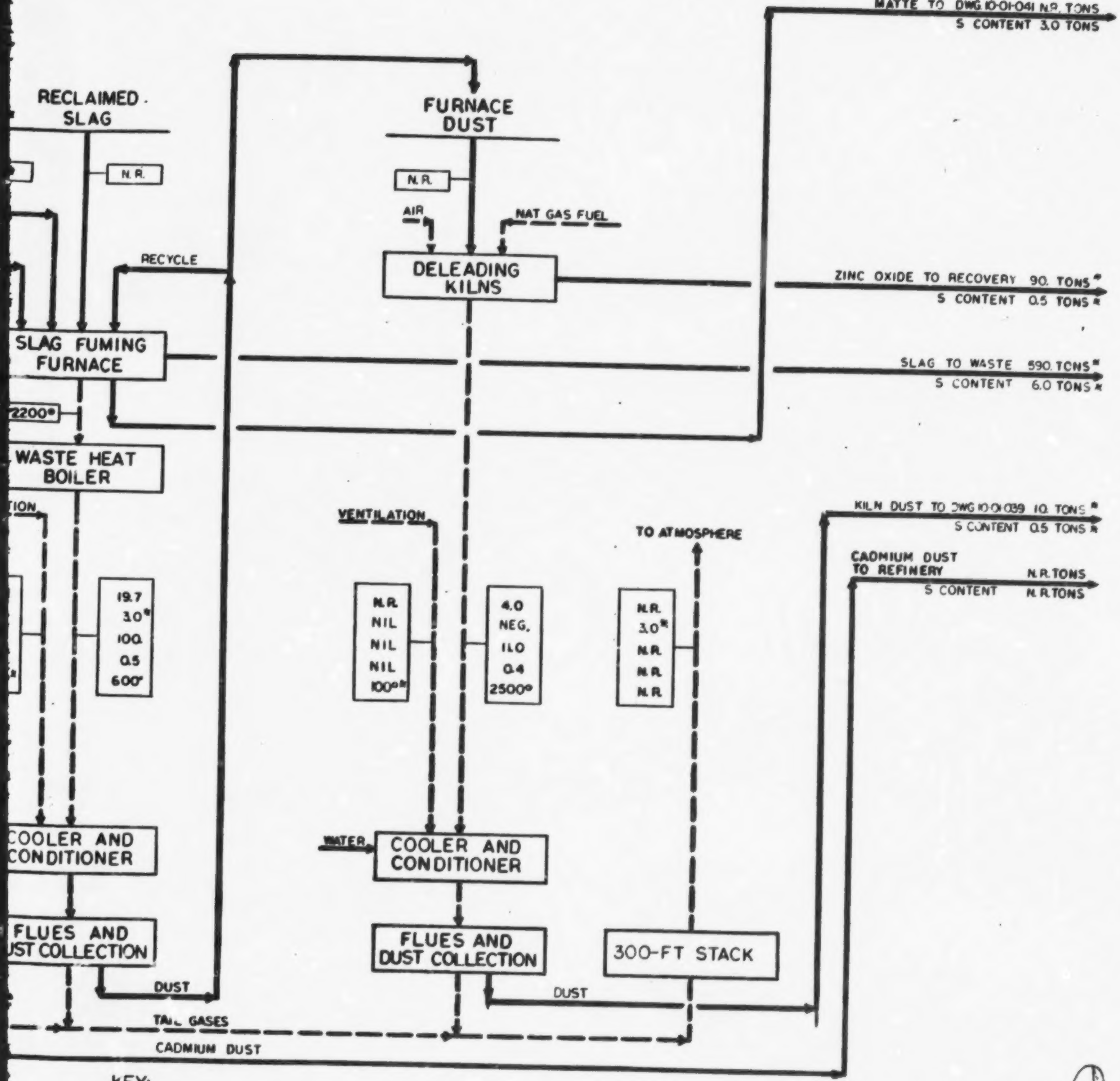
PLATE NO. A-42


LEAD PLANT DUST
FROM DWG. 10-01-039
LEAD PLANT SLAG
FROM DWG. 10-01-039
S TONS
N.R.
N.R.
COAL
N.R.
3.0*
RECLAIMED SLAG
7.2
N.R.
COAL PULVERIZER
COAL
RECYC
NAT GAS FUEL
LEAD DUST
FROM
DWG. 10-01-022
AIR
CADMIUM ROASTER
AIR
SLAG FUMING FURNACE
ACTUAL TEMP F
2200°
WASTE HEAT BOILER
VENTILATION
VENTILATION
GAS 1000 SCFM
S IN GAS TONS
DUST IN TONS
S IN DUST TONS
ACTUAL TEMP F
N.R.
NEG
N.R.
N.R.
N.R.
N.R.
NIL
NIL
NIL
100°*
18.0
0
0
0
100°
N.R.
NIL
NIL
NIL
100°*
19.7
3.0*
100
0.5
600°
WATER
COOLER AND CONDITIONER
BLOWER
WATER
COOLER AND CONDITIONER
FLUES AND DUST COLLECTION
FLUES AND DUST COLLECTION
DUST
TAIL
CADM

BASIS:
TONNAGES ARE GIVEN
FOR A 24-HOUR PERIOD
IN SHORT TONS

S-SULFUR

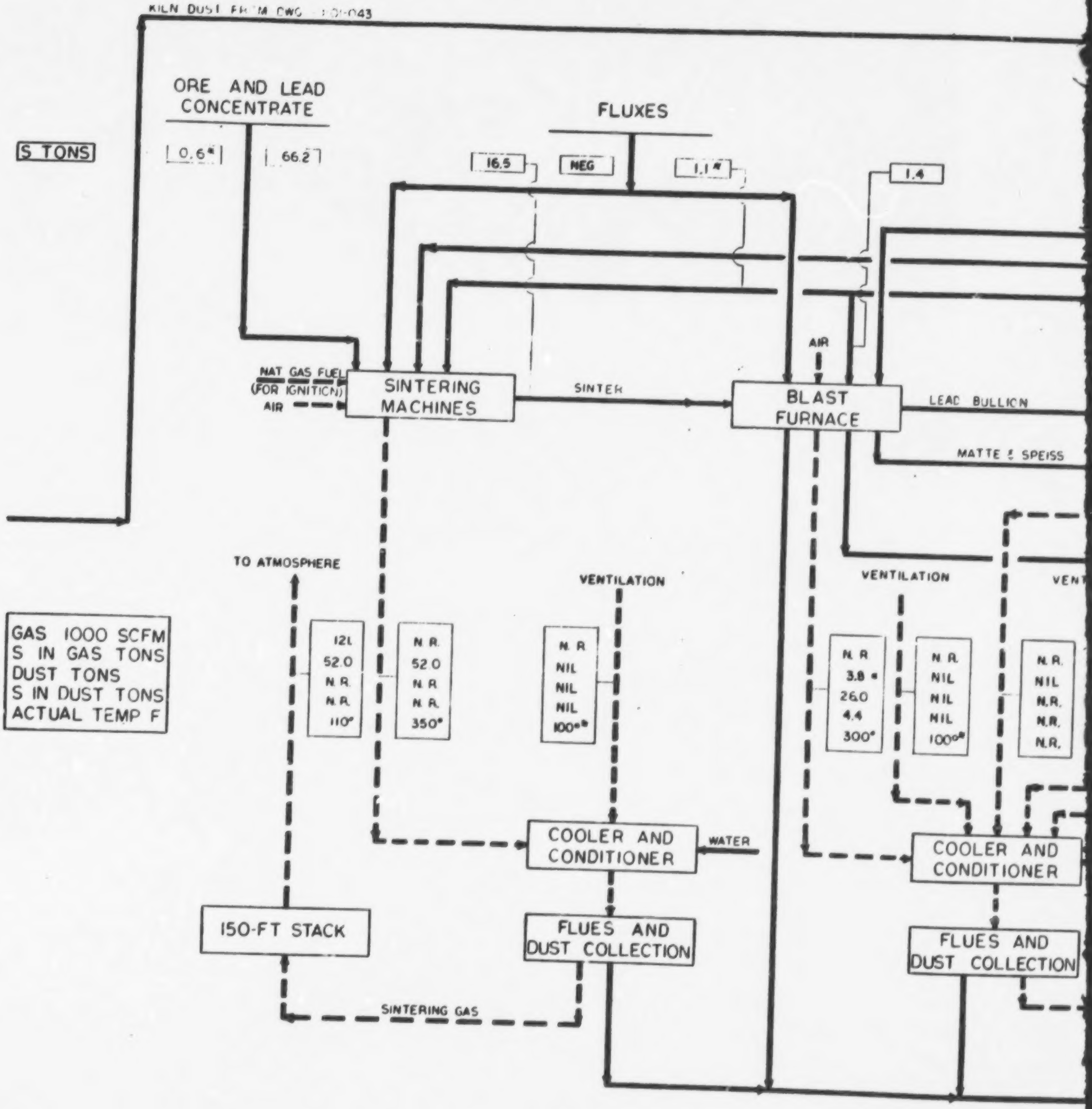
KEY:
NEG.-NEG
NIL.- NEG
N.R.-NOT
SOLIDS &
GASES
SCFM ME
AND ONE
* - ESTI


RECLAIMED SLAG
N.R.
FURNACE DUST
N.R.
AIR
NAT GAS FUEL
RECYCLE
DELEADING KILNS
MATTE TO DWG.10-01-041 N.R. TONS
S CONTENT 3.0 TONS
ZINC OXIDE TO RECOVERY 90. TONS*
S CONTENT 0.5 TONS*
SLAG FUMING FURNACE
SLAG TO WASTE 590. TONS*
S CONTENT 6.0 TONS*
2200°
WASTE HEAT BOILER
TION
VENTILATION
TO ATMOSPHERE
KILN DUST TO DWG.10-01-039 10. TONS*
S CONTENT 0.5 TONS*
CADMIUM DUST TO REFINERY N.R. TONS
S CONTENT N.R. TONS
19.7
3.0*
100.
0.5
600°
N.R.
NIL
NIL
NIL
100°*
4.0
NEG.
11.0
0.4
2500°
N.R.
3.0*
N.R.
N.R.
N.R.
COOLER AND CONDITIONER
WATER
COOLER AND CONDITIONER
FLUES AND UST COLLECTION
FLUES AND DUST COLLECTION
300-FT STACK
DUST
DUST
TAIL GASES
CADMIUM DUST

KEY:
NEG.-NEGLECTED(MINOR QUANTITY PRESENT, BUT NOT REPORTED OR ESTIMATED)
NIL.-NEGLECTED(INSIGNIFICANT QUANTITY NOT AFFECTING MATERIAL BALANCE)
N.R.-NOT REPORTED (QUANTITY UNKNOWN)
SOLIDS & LIQUIDS ▬▬▬
GASES ‒ ‒ ‒ ‒
SCFM MEASURED AT 32° F
AND ONE ATMOSPHERE
* - ESTIMATED QUANTITY

B

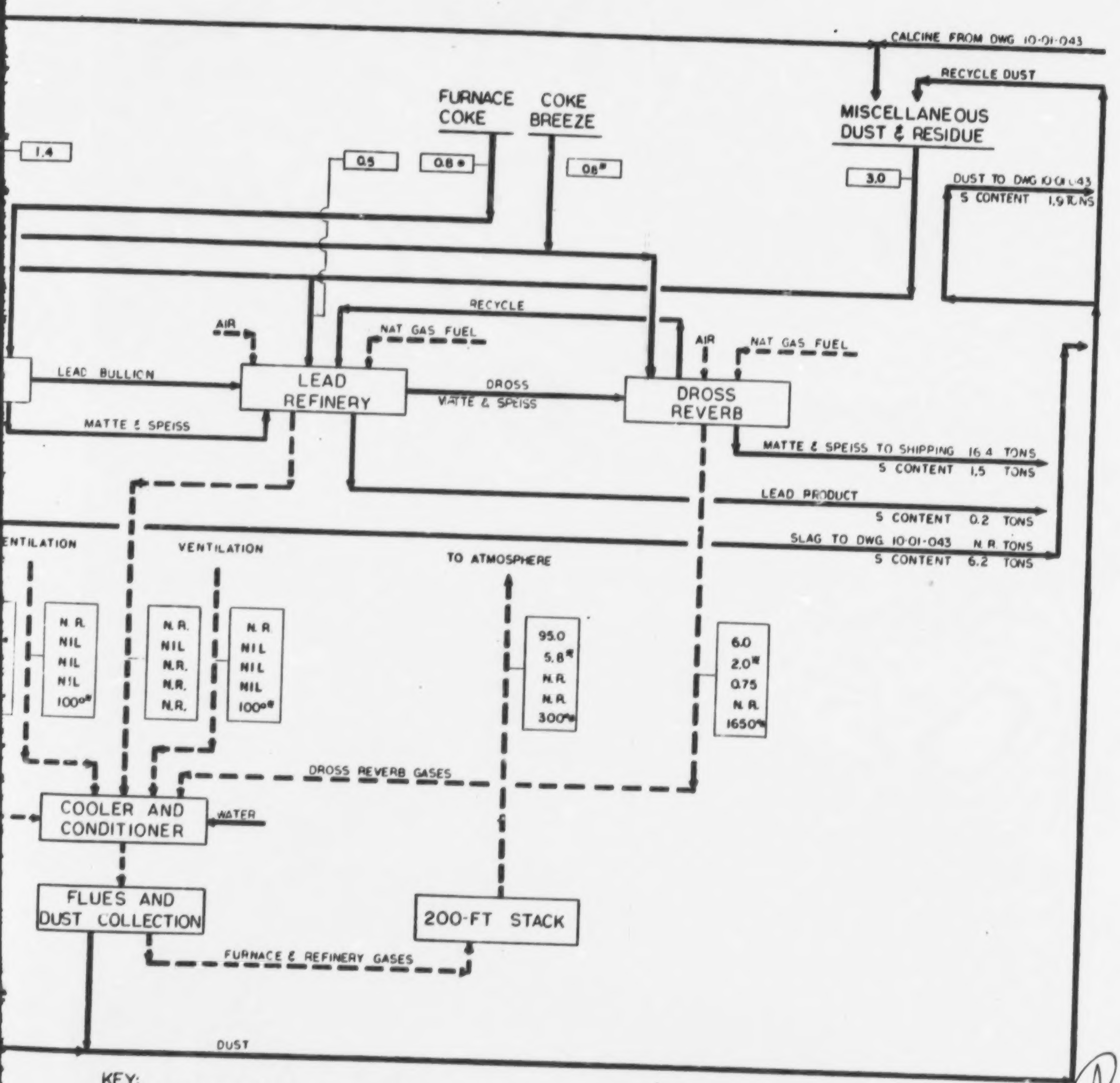
NATIONAL AIR POLLUTION CONTROL ADMINISTRATION	ARTHUR G. McKEE & COMPANY WESTERN KNAPP ENGINEERING DIVISION SAN FRANCISCO CALIFORNIA
326.33 LEAD PLANT BYPRODUCTS FLOW DIAGRAM	ENG. DEPT. DWG. 10-01-040 PLATE NO. A-43


KILN DUST FROM DWG 01-043
ORE AND LEAD CONCENTRATE
S TONS
0.6*
66.2
FLUXES
16.5
NEG
1.1*
1.4
NAT GAS FUEL (FOR IGNITION)
AIR
SINTERING MACHINES
SINTER
AIR
BLAST FURNACE
LEAD BULLION
MATTE & SPEISS
TO ATMOSPHERE
VENTILATION
VENTILATION
VENT
GAS 1000 SCFM
S IN GAS TONS
DUST TONS
S IN DUST TONS
ACTUAL TEMP F
121
52.0
N.R.
N.R.
110°
N.R.
52.0
N.R.
N.R.
350°
N.R.
NIL
NIL
NIL
100°*
N.R.
3.8*
26.0
4.4
300°
N.R.
NIL
NIL
NIL
100°*
N.R.
NIL
N.R.
N.R.
N.R.
COOLER AND CONDITIONER
WATER
COOLER AND CONDITIONER
150-FT STACK
FLUES AND DUST COLLECTION
FLUES AND DUST COLLECTION
SINTERING GAS

BASIS:
TONNAGES ARE GIVEN FOR A 24-HOUR PERIOD IN SHORT TONS

S - SULFUR

KEY:
NEG NEGLEC
NIL-NEGLEC
N.R.-NOT RE
SOLIDS & LI
GASES
SCFM MEAS
AND ONE AT
* - ESTIMAT


CALCINE FROM DWG 10-01-043
RECYCLE DUST
FURNACE COKE
COKE BREEZE
MISCELLANEOUS DUST & RESIDUE
1.4
0.5
0.8*
0.8*
3.0
DUST TO DWG 10-01-043
S CONTENT 1.9 TONS
RECYCLE
AIR
NAT GAS FUEL
AIR
NAT GAS FUEL
LEAD BULLION
LEAD REFINERY
MATTE & SPEISS
DROSS
MATTE & SPEISS
DROSS REVERB
MATTE & SPEISS TO SHIPPING 16.4 TONS
S CONTENT 1.5 TONS
LEAD PRODUCT
S CONTENT 0.2 TONS
SLAG TO DWG 10-01-043 N.R. TONS
S CONTENT 6.2 TONS
ENTILATION
VENTILATION
TO ATMOSPHERE
N.R. NIL NIL NIL 100°*
N.R. NIL N.R. N.R. N.R.
N.R. NIL NIL NIL 100°*
95.0 5.8* N.R. N.R. 300°*
6.0 2.0* 0.75 N.R. 1650°*
DROSS REVERB GASES
COOLER AND CONDITIONER
WATER
FLUES AND DUST COLLECTION
200-FT STACK
FURNACE & REFINERY GASES
DUST

KEY:
NEG-NEGLECTED (MINOR QUANTITY PRESENT, BUT NOT REPORTED OR ESTIMATED)
NIL-NEGLECTED (INSIGNIFICANT QUANTITY NOT AFFECTING MATERIAL BALANCE)
NR-NOT REPORTED (QUANTITY UNKNOWN)
SOLIDS & LIQUIDS ▬▬
GASES ‒ ‒ ‒
SCFM MEASURED AT 32°F
AND ONE ATMOSPHERE
* - ESTIMATED QUANTITY

B

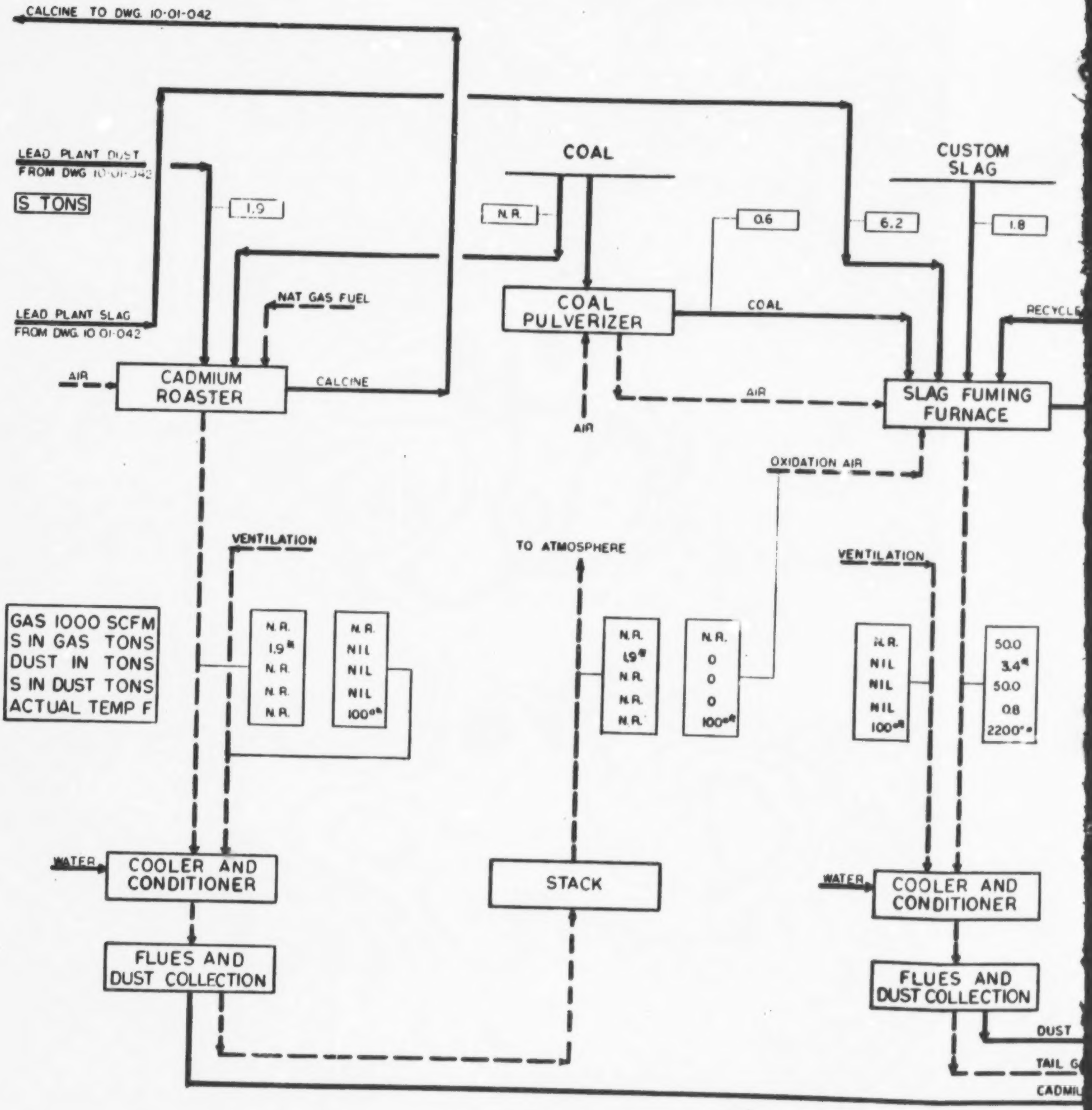
CLIENT
NATIONAL AIR
POLLUTION CONTROL
ADMINISTRATION

TITLE
326.34
LEAD PLANT
FLOW DIAGRAM

ARTHUR G. McKEE & COMPANY
WESTERN KNAPP ENGINEERING DIVISION
SAN FRANCISCO CALIFORNIA

ENG. DEPT. DWG. 10-01-042

PLATE NO. A-44

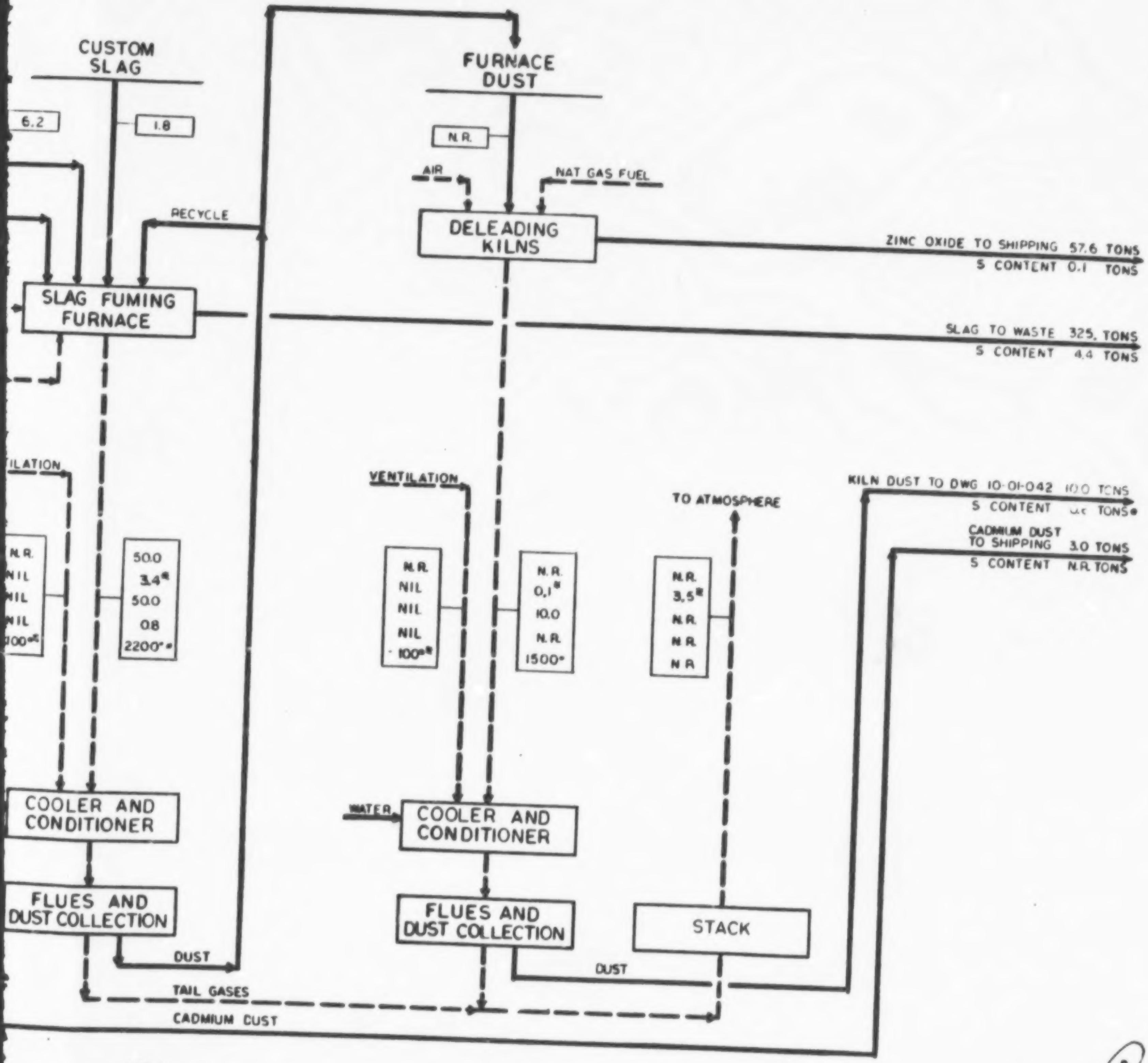


CALCINE TO DWG. 10-01-042
LEAD PLANT DUST FROM DWG 10-01-042
S TONS
1.9
COAL
N.R.
0.6
CUSTOM SLAG
6.2
1.8
LEAD PLANT SLAG FROM DWG 10-01-042
NAT GAS FUEL
COAL PULVERIZER
COAL
RECYCLE
AIR
CADMIUM ROASTER
CALCINE
AIR
AIR
SLAG FUMING FURNACE
OXIDATION AIR
VENTILATION
TO ATMOSPHERE
VENTILATION
GAS 1000 SCFM
S IN GAS TONS
DUST IN TONS
S IN DUST TONS
ACTUAL TEMP F
N.R. 1.9* N.R. N.R. N.R.
N.R. NIL NIL NIL 100°*
N.R. 1.9* N.R. N.R. N.R.
N.R. 0 0 0 100°*
N.R. NIL NIL NIL 100°*
50.0 3.4* 50.0 0.8 2200°*
WATER
COOLER AND CONDITIONER
STACK
WATER
COOLER AND CONDITIONER
FLUES AND DUST COLLECTION
FLUES AND DUST COLLECTION
DUST
TAIL G
CADMIU

BASIS:
TONNAGES ARE GIVEN
FOR A 24-HOUR PERIOD
IN SHORT TONS

S-SULFUR

KEY:
NIL- NEGL
N.R.-NOT
SOLIDS &
GASES
SCFM MEA
AND ONE
* - ESTIM


CUSTOM SLAG
6.2
1.8
RECYCLE
SLAG FUMING FURNACE
FURNACE DUST
N.R.
AIR
NAT GAS FUEL
DELEADING KILNS
ZINC OXIDE TO SHIPPING 57.6 TONS
S CONTENT 0.1 TONS
SLAG TO WASTE 325. TONS
S CONTENT 4.4 TONS
VENTILATION
N.R.
NIL
NIL
NIL
50.0
3.4*
50.0
0.8
2200°*
VENTILATION
N.R.
NIL
NIL
NIL
100°*
N.R.
0.1*
10.0
N.R.
1500°
TO ATMOSPHERE
N.R.
3.5*
N.R.
N.R.
N.R.
KILN DUST TO DWG 10-01-042 10.0 TONS
S CONTENT TONS*
CADMIUM DUST TO SHIPPING 3.0 TONS
S CONTENT N.R. TONS
COOLER AND CONDITIONER
FLUES AND DUST COLLECTION
DUST
WATER
COOLER AND CONDITIONER
FLUES AND DUST COLLECTION
STACK
DUST
TAIL GASES
CADMIUM DUST

B

KEY:
NIL - NEGLECTED (INSIGNIFICANT QUANTITY NOT AFFECTING MATERIAL BALANCE)
N.R. - NOT REPORTED (QUANTITY UNKNOWN)
SOLIDS & LIQUIDS ▬▬
GASES ‐ ‐ ‐
SCFM MEASURED AT 32° F
AND ONE ATMPHERE
* - ESTIMATED QUANTITY

CLIENT
NATIONAL AIR
POLLUTION CONTROL
ADMINISTRATION

TITLE
326.34
LEAD PLANT BYPRODUCTS
FLOW DIAGRAM

ARTHUR G. McKEE & COMPANY
WESTERN KNAPP ENGINEERING DIVISION
SAN FRANCISCO CALIFORNIA

ENG. DEPT. DWG. 10-01-043

PLATE NO. A-45

APPENDIX B

SULFUR OXIDE CONTROL PROCESSES

	Pages
Rejected control processes	B - 1 to - 23
Bibliography for control processes	B - 24 to - 30

Control Process Cost Estimates:

Table No.	
B - 1	Sulfuric acid - capital cost
B - 2	operating cost
B - 3	Cominco absorption - capital cost
B - 4	operating cost
B - 5	Asarco reduction - capital cost
B - 6	operating cost
B - 7	Lime & limestone wet-scrubbing - capital cost
B - 8	Lime wet-scrubbing - lime burning section - operating cost
B - 9	Limestone wet-scrubbing - limestone fine-grinding section - operating cost
B - 10	Lime & limestone wet-scrubbing - scrubbing and waste-treating section - operating cost

Control Process Flow Diagrams:

Plate No.	
B - 1	Sulfuric acid - 2% SO_2 in offgas
B - 2	4% SO_2 in offgas
B - 3	8% SO_2 in offgas
B - 4	12% SO_2 in offgas

REJECTED CONTROL PROCESSES

The processes listed here are sulfur oxide recovery processes that were investigated and rejected as not being suitable as subjects for economic analysis in this project. Reasons for rejection are stated. References are made to literature cited in "Bibliography for Recovery Processes" in this appendix.

Alkalized Alumina

Sponsors: U.S. Bureau of Mines; CEGB, England

Process description: Flue gas is contacted with a hot bed of alkalized alumina, which absorbs sulfur oxides. The alumina catalyst is removed from the flue gas and treated with a reducing gas to convert the sulfur oxides to hydrogen sulfide and to regenerate the alumina for recycling. The hydrogen sulfide is converted to sulfur by the Claus process. Reducing gas is generated from coal, oil or (most probably) natural gas.

Two versions of the process are presently under study: the flue gas contactor may be a dense phase fluidized bed (CEGB) or a dilute phase, air-lift type of reactor (U.S. Bureau of Mines).

Absorbing medium: Alkalized alumina

End product: Elemental sulfur

Stage of development: Extensive research and development in various pilot plants. Application presently being studied for a 50-mw power station in England.

Particular applications: Mainly for gases of low sulfur dioxide concentration (e.g., power station flue gases). It would work well on high concentration gases, but may be uneconomic compared with other recovery methods.

Other information: Costs have been estimated for various sizes of plants operating under different conditions.

Reason for rejection: This may well prove to be a satisfactory, economic process. However, at the present moment, there is considerable uncertainty both as to which of the two versions mentioned above will be better, and as to the extent of catalyst attrition, which has a critical effect on the process economics.

McKee studied the literature available on this process and a McKee engineer visited the Bureau of Mines laboratories in Albany, Oregon, where tests are being made of absorbing media durability and capacity. After extensive investigation McKee recommended and NAPCA agreed that an economic analysis of alkalized alumina should not be made a part of this report. The process is being adequately studied separately from this project.

References: Rg-2, 3, 4, 5, 9, 12, 16, 20

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Ammonia Absorption

Sponsor: Mitsubishi Industries, also Showa-Denko

Process description: Sulfur oxides are absorbed in a weak ammonia solution, which may then be oxidized to ammonium sulfate by air blowing.

Absorbing medium: Ammonia solution

End product: Ammonium sulfate

Stage of development: Process under development by Mitsubishi in Japan, and some pilot plant work conducted. Showa-Denko has had a 25-mw test unit operating since 1966.

Reason for rejection: For smelter gases, the Cominco version of the ammonia absorption process appears more promising than either the Mitsubishi or Showa-Denko. The Cominco process is being studied under this contract.

References: Rg-1, 12

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Ammonia - Hydrazine

Sponsor: Aerojet General

Process description: Two versions of this process have been described. In both versions, sulfur dioxide is absorbed in an aqueous solution of hydrazine, which is then either steam stripped to release sulfur dioxide or oxidized to produce ammonium sulfate. The hydrazine may be recycled, if desired.

Absorbing medium: Hydrazine solution

End products: Sulfur dioxide, ammonium sulfate

Stage of development: Paper study, only, for both versions.

Reason for rejection: Lack of data, together with the fact that this is similar to ammonia absorption processes, especially the Cominco process that is being studied under this contract. Hydrazine is also considerably more expensive than ammonia.

Reference: Rg-1

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Basic Aluminum Sulfate

Sponsors: Imperial Chemical Industries

Process description: Scrubber effluent containing aluminum bisulfite/sulfate is heated to release sulfur dioxide and regenerate basic aluminum sulfate. Some oxidation to aluminum sulfate occurs; calcium carbonate is added to precipitate calcium sulfate, which is separated and discarded.

Absorbing medium: Basic aluminum sulfate

End product: Sulfur dioxide, calcium sulfate

Stage of development: First commercial plant at Imatra, Finland (1936-41) operating on smelter gas. Plant at Manchester, England in operation since 1958.

Reason for rejection: Low capacity results in large expensive scrubbing system.

References: Rg-1, 6, 8, 19

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Battersea

Sponsors: CEGB, England

Process description: Water from an alkaline river (River Thames) is used to scrub flue gases from power plant. Manganese sulfate is added to convert calcium sulfite to sulfate, which is more suitable for river disposal.

Absorbing medium: River water containing lime

End product: Calcium sulfate

Stage of development: Several British power plants are equipped with units.

Reason for rejection: Very limited applicability: The plant or power station needs to be beside a river with a high alkaline content. In addition, there is some question of water pollution.

Reference: Rg-1, 6

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Chevron

Sponsor: Chevron Research

Process description: Carbon monoxide is introduced into flue gas stream and reduces sulfur dioxide to sulfur on a catalyst.

Reducing medium: Carbon monoxide

End product: Elemental sulfur

Stage of development: Laboratory test work

Other information: Process is similar to the old Asarco process, which used natural gas as a reducing agent, and the PRA process currently under study.

Reason for rejection: The process has not been sufficiently developed to allow a realistic appraisal.

Reference: Rg-5

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Chromatographic

Sponsor: U.S. Bureau of Mines

Process description: Adsorption of sulfur dioxide on a solid surface in a thin bed, and thermal regeneration within the same piece of equipment.

Adsorbing media: Various

End product: Concentrated sulfuric acid

Stage of development: Bench scale laboratory tests.

Other information: A preliminary cost estimate has been prepared by the Bureau of Mines.

Reason for rejection: The process is in a very early stage and very little data is available.

References: Rg-2, 20

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Cupric Oxide

Sponsor: U.S. Bureau of Mines

Process description: Flue gas is passed over a bed of cupric oxide, the sulfur dioxide is absorbed and converted to cupric sulfate. This is regenerated by heating; sulfur dioxide is recovered as a gas.

Absorbing medium: Cupric oxide

End product: Sulfur dioxide

Stage of development: Paper study only (1958)

Reason for rejection: No further work was done on this process by the sponsor.

Reference: Rg-6

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Direct Compression

Sponsor: Canadian Industries, Ltd.

Process description: Gas is scrubbed and passed through precipitator, then dried and compressed to 120 psig. Liquid sulfur dioxide is discharged to storage.

Absorbing medium: Not applicable

End product: Liquid sulfur dioxide

Stage of development: Pilot plant 1947-1948 with capacity of five tons per day.

Reason for rejection: Process was abandoned by sponsor due to high power costs.

Reference: Rg-8

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"Fouled" Huff Catalyst

Sponsor: U.S. Bureau of Mines

Process description: "Fouled" Huff Catalyst, containing oxides of copper, chromium, and vanadium, was found to completely absorb sulfur dioxide in low concentrations.

Stage of development: Paper study (1958)

Reason for rejection: No further work was done on this process.

Reference: Rg-6

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Fulham-Simon-Carves

Sponsor: Simon Carves

Process description: Sulfuric acid added to scrubber effluent and mixture autoclaved to produce ammonium sulfate and sulfur.

Absorbing Medium: Ammonia

End product: Ammonium sulfate, sulfur

Stage of development: Extensive pilot plant scale in England.

Reason for rejection: This process depends on the sale of ammonium sulfate for economic viability, and ammonium sulfate has a poor market in the U.S. .

References: Rg-1, 6, 23

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Guggenheim

Sponsor: American Smelting & Refining Co.

Process description: Sulfur dioxide is steam-stripped from scrubber effluent, then reduced with coke to sulfur. Ammonium sulfate solution is treated with lime to regenerate ammonia, which is reused; byproduct calcium sulfate is discarded.

Absorbing medium: Ammonia

End product: Sulfur, calcium sulfate

Stage of development: Pilot plant at Garfield, Utah in 1940's, on smelter gas.

Reason for rejection: Process was abandoned by sponsor due to unfavorable process economics.

References: Rg-1, 8

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Haenisch-Schroeder

Process developed in late 1800's.

Process description: Lime added to scrubber effluent to separate the sulfate formed on oxidation as calcium sulfate. Liquid is then treated to release sulfur dioxide.

Absorbing medium: Water

End products: Sulfur dioxide, calcium sulfate

Reason for rejection: Extremely high operating cost due to large consumption of stripping steam.

References: Rg-1, 8, 19

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Hitachi Process (Carbon Absorption)

Sponsor: Hitachi Ltd., Japan

Process description: Similar to Lurgi Sulfacid, except that several contactors in parallel are used, with batch washing of char. This minimizes gas cooling.

Absorbing medium: Activated char

End product: Weak sulfuric acid

Stage of development: Two-megawatt test unit being operated, 50-mw unit planned.

Reason for rejection: Same objections as Lurgi Sulfacid, with the additional problem of costly flue gas dampers.

Reference: Rg-12

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Ionics

Sponsor: Ionics, Inc.

Process description: Sulfur dioxide is absorbed in a solution of caustic soda and sodium bisulfate. The solution is regenerated by electrolysis.

Absorbing medium: Solution of caustic soda and sodium bisulfate

End product: Sulfur dioxide

Stage of development: Demonstration plant is in the planning stage.

Reason for rejection: This is a very new process and no data is available for an economic evaluation.

References: Rg-9, 14

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Kanagawa

Process studied in Japan

Process description: Process reportedly offers an improved method for attaining intimate contact between water and gas stream.

Absorbing medium: Sea water, natural underground water, or alkalized water.

End product: not specified

Stage of development: Pilot plant studies in Japan

Reason for rejection: Insufficient data, coupled with the fact that this is a version of the Haenisch-Schroeder, which has high operating costs.

Reference: Rg-1

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Kiyoura - T.I.T.

Sponsor: Kiyoura/Tokyo Institute of Technology

Process description: The flue gas is catalytically treated to oxidize sulfur dioxide to sulfur trioxide, then treated with ammonia to form ammonium sulfate.

Reacting medium: Ammonia gas

End product: Ammonium sulfate crystals

Stage of development: Pilot plant

Reason for rejection: The process is a modified catalytic oxidation producing ammonium sulfate as a product: this has a poor market in this country and hence is at a disadvantage compared with the normal catalytic oxidation processes.

References: Rg-5, 12

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Lead Dioxide

Sponsor: U.S. Bureau of Mines

Process description: Sulfur dioxide is absorbed by dry lead dioxide, which is converted to the sulfate. The lead sulfate is then electrolyzed to form lead dioxide and sulfuric acid.

Absorbing medium: lead dioxide

End product: Sulfuric acid

Stage of development: Paper study only

Reason for rejection: No further work was done on this process by the sponsor.

Reference: Rg-6

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Lignite Ash

Sponsor: Firma Carl Still Germany

Process description: Ash from lignite combustion is hydrated, then contacted with the flue gas in an entrainment-type reactor. Calcium sulfite produced is then heated to produce sulfur dioxide and lime, the latter being recycled.

Absorbing medium: Lignite ash

End product: Sulfur dioxide, impure calcium sulfate

Stage of development: 10-mw power plant test unit at Heine, Germany

Reason for rejection: Process appears similar to dry limestone process, which has serious drawbacks. (See "Limestone (Dry Process)"). In addition, lignite ash is not widely available.

Reference: Rg-12

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Limestone (Dry Process)

Sponsors: Battelle Memorial Institute, NAPCA, Combustion Engineering, Esso Research, TVA and others.

Process description: Calcium oxide (and sometimes magnesium oxide) is injected into the gas stream and products are collected in a precipitator or bag house. In a coal-fired power boiler, limestone or dolomite is fired with the fuel; in a smelter, lime would have to be produced separately in a kiln and contacted with the offgas stream.

Absorbing medium: Calcium or magnesium oxides

End product: Calcium or magnesium sulfites and sulfates (discarded)

Stage of development: Extensive research, and installation in several power plants.

Reason for rejection: Apparently limestone quantities considerably in excess of stoichiometric are needed to achieve reasonable efficiencies. The wet limestone process is superior in that near-stoichiometric quantities of lime achieve a high removal efficiency, and the wet scrubber is considerably less expensive.

References: Rg-5, 9, 15, 20

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Magnesium Hydroxide

Sponsors: Process covered by 1952 British patent, also work done in USSR

Process description: Insoluble magnesium sulfite is oxidized to the soluble sulfate, then reacted with ammonia to give magnesium hydroxide and ammonium sulfate.

Absorbing medium: Suspension of magnesium hydroxide

Product: Ammonium sulfate

Stage of development: Not known

Reasons for rejection: Process economics depend on sale of ammonium sulfate, which has a poor market in this country.

References: Rg-1, 6

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Magnesium Oxide

Sponsors: Researchers in USSR (1956)

Process description: Magnesium bisulfite is formed in scrubber and neutralized with magnesium oxide to form the sulfite, which is then calcined to yield sulfur dioxide and magnesium oxide. The magnesium oxide is then recycled.

Absorbing medium: Suspension of magnesium oxide

End product: Sulfur dioxide, magnesium sulfate

Stage of development: Pilot plant

Reason for rejection: According to previous researchers, this process is less satisfactory than its main rival, the zinc oxide process.

Reference: Rg-1

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Manganese Dioxide (Wet process)

Sponsor: Tennessee Valley Authority

Process description: Soluble manganese sulfate and dithionate are formed by reaction of the sulfur dioxide with manganese dioxide, then autoclaved. The precipitate is calcined to yield sulfur dioxide and manganese dioxide; the latter is recycled.

Absorbing medium: Suspension of manganese dioxide

End product: Sulfur dioxide

Stage of development: Pilot plant studies

Reason for rejection: The manganese dioxide is less satisfactory than the zinc oxide process, which is similar. Work on this manganese dioxide process was stopped by the sponsor.

References: Rg-1, 6

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Manganese Dioxide (Dry Process)

Sponsor: Mitsubishi Industries, Japan

Process description: Dry manganese dioxide is injected into the gas stream and is partially converted to manganese sulfate. Ninety percent of solids collected are recycled directly; the other ten percent are slurried with water and contacted with air and ammonia to form ammonium sulfate and manganese dioxide. The manganese dioxide is recycled.

Absorbing medium: Dry manganese dioxide

End product: Ammonium sulfate

Stage of development: 55-mw power plant equipped with this unit (end of 1967)

Reason for rejection: Process depends on sale of ammonium sulfate, which has a poor market in the U.S., and hence would make the process noncompetitive in this country.

Reference: Rg-12

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Manganese Ore Leaching

Sponsor: Bureau of Mines and others

Process description: Manganese ores are leached by alternately passing sulfur dioxide-bearing gas streams through the moistened ore, followed by treatment with wash solutions to extract soluble manganese compounds. One Bu Mines process uses a high-temperature differential sulfatization process to form water-soluble manganese sulfate.

Absorbing medium: Manganese ore

End product: Manganese hydroxide or oxide

Stage of development: Pilot plant and semi-commercial plant studies of about ten different process variations, beginning in World War I and continuing at various times and under various sponsors into the present decade.

Reason for rejection: Large tonnages of manganese ore are required, which would not be economically available at more than a few smelter locations. The processes are primarily for manganese extraction and only incidentally a means of removing sulfur oxides from gas streams. A ton of manganese in the ore is needed for removal of two tons of sulfur dioxide from the gas.

References: Rg-21, 22, 25

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Manganese Oxyhydroxide

Sponsor: Mitsubishi Industries, Japan

Process description: Manganese sulfate formed in the absorption process is treated with ammonia and oxygen regenerating the manganese oxyhydroxide and producing ammonium sulfate.

Absorbing medium: Suspension of manganese oxyhydroxide

End product: Ammonium sulfate

Stage of development: Pilot plant

Reason for rejection: Since this process includes the absorption of ammonia and oxidation to ammonium sulfate, it is a rival to the ammonia absorption processes. The most promising of these, the Cominco process, is being studied under this contract.

Reference: Rg-1

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Mitsubishi Red Mud

Sponsor: Mitsubishi Industries, Japan

Process description: Sodium aluminum silicate present in "red mud" reacts with sulfur dioxide to give sodium sulfate.

Absorbing medium: Suspension of residue from extraction of alumina from bauxite

End product: Mud containing sodium sulfate

Stage of development: Pilot plant

Reason for rejection: Very limited applicability. Plant would need to be near a bauxite refinery, otherwise shipping costs for the red mud would render the process uneconomic.

Reference: Rg-1

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Mixed Metal Oxides (Grillo)

Sponsor: A.G. fur Zinkindustrie vorm Wilhelm Grillo, Germany

Process description: The mixed metal oxides and alkaline earth hydroxide are deposited on a carrier (coke) and contacted with flue gas. Absorbent separated from coke by screening, mixed with coal, and regenerated at 900 C to produce a gas stream that is burned to yield sulfur dioxide. The regenerated catalyst is water-quenched and recycled.

Absorbing medium: Mixed metal oxides/hydroxides, typically manganese dioxide and magnesium hydroxide.

End product: Sulfur dioxide

Stage of development: Eight-mw power plant unit constructed in Cologne, Germany in mid 1967.

Reason for rejection: Development has not sufficiently advanced to allow a realistic economic evaluation.

Reference: Rg-12

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Molten Carbonate

Sponsor: North American Rockwell/NAPCA

Process description: Flue gases are bubbled through molten carbonates to remove sulfur dioxide. The salts are then regenerated, either with carbon followed by water, or with producer gas.

Absorbing medium: Molten carbonate salts.

End product: Hydrogen sulfide

Stage of development: Laboratory tests

Reason for rejection: Process is not sufficiently developed to allow meaningful cost estimates to be made.

References: Rg-9, 10, 11, 20, 24

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Ozone - Manganese Ion

Sponsor: Tennessee Valley Authority

Process description: Ozone added to flue gas promotes oxidation of sulfur dioxide to trioxide, with manganese sulfate acting as a catalyst.

Absorbing medium: Water containing ozone and manganese sulfate.

End product: Dilute sulfuric acid

Stage of development: Laboratory test work

Reason for rejection: Process was abandoned by sponsor due to unsatisfactory results. A large, expensive scrubber is needed to compensate for the low absorption rate and capacity. The byproduct is not salable.

References: Rg-1, 19

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P.C.R.

Sponsors: Princeton Chemical Research/NAPCA

Process description: Elemental sulfur is reacted catalytically with methane (natural gas) to form hydrogen sulfide, which is then mixed with flue gas to react with the sulfur dioxide of the flue gas to form elemental sulfur. The sulfur is recovered and a portion is diverted for conversion to hydrogen sulfide.

Reacting medium: Hydrogen sulfide

End product: Elemental sulfur

Stage of development: Laboratory test work

Reason for rejection: This process is in an early stage of development, and data available are insufficient for an economic evaluation.

Reference: Rg-18

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Reduction with Coke

Sponsors: Imperial Chemical Industries, (ICI), Bolidens, Cominco

Process description: In the ICI version, 100 percent sulfur dioxide is passed through hot coke. The gases then pass through a waste heat boiler where sulfur condenses, then through a precipitator and a scrubber.

The Boliden version treats roaster gases (typically five percent sulfur dioxide) that are passed through hot coke, then bypassed roaster gas is added and the combined stream passes through two catalyst chambers, is cooled and passed through a third catalyst chamber, then cooled finally and scrubbed.

Absorbing and reacting medium: Coke

End product: Sulfur

Stage of development: Several plants built and operated satisfactorily.

Reason for rejection: The direct reduction with natural gas is considered to be a better process, and is being studied under this contract.

References: Rg-6, 7

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Reinluft (Activated Char)

Sponsor: Reinluft, Germany

Process description: Sulfur dioxide absorbed on char, oxidized to trioxide, char contacted with steam to form sulfuric acid. Char is then regenerated by thermally decomposing the sulfuric acid to sulfur dioxide, which is then converted in an acid plant to sulfuric acid.

Absorbing medium: Activated char

End product: Sulfuric acid

Stage of development: Three full scale plants in operation, the largest being one in Wolfsburg, Germany, to treat 80,000 normal cubic meters per hour.

Particular applications: Suitable for low concentration gases, such as power plant flue gases.

Other information: Capital and operating costs have been estimated for full scale plants.

Reason for rejection: The process has many operating problems, high capital and operating cost, and a severe danger of explosion which may make the process unacceptable.

References: Rg-2, 12, 16

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Soda Ash Scrubbing

Sponsor: UOP/Wisconsin Power Co.; Peabody

Process description: Flue gas is scrubbed with a sodium carbonate solution to remove flyash and sulfur dioxide. The waste products are discarded.

The Peabody version treats 75 percent of the flue gas, the other 25 percent bypasses the scrubber and is used to "reheat" the quenched gases.

Absorbing medium: Sodium carbonate solution

End product: Sodium sulfite

Stage of development: Paper study (Peabody); 25-mw power plant in operation (Wisconsin Power Co.)

Reason for rejection: The sodium carbonate used in the process costs considerably more (2 to 4 times) than the lime used in the similar wet-lime process, and hence operating costs will be higher than the wet lime process. In addition there is not enough soda ash available to allow application of this process on a large scale, unless expensive regeneration is included.

References: Rg-5, 17

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Sulfacid Process

Sponsor: Lurgi Apparatebau, Germany

Process description: Sulfur dioxide is adsorbed and converted to sulfuric acid on a fixed bed of char. At the same time, the char is washed with water countercurrent to the flue gases to remove the acid and regenerate the char. If a venturi scrubber is used to wash the gases, the resulting acid solution will be 25 to 30 percent concentration; otherwise the acid is 10 to 15 percent. The exit flue gases are cool and saturated with water.

Adsorbing medium: Activated char

End product: Dilute sulfuric acid

Stage of development: Pilot plant testwork. Tests planned (December 1967) in coal-burning power plant.

Particular applications: Sulfur dioxide concentrations between 0.1 and 1.5 percent. Above these concentrations, the sponsor recommends dilution with air.

Other information: Preliminary cost data for capital and operating costs have been developed by the sponsor.

Reason for rejection: High concentration gases in the smelter industry would have to be diluted and consequently capital costs would be high. The dilute acid produced has poor market value; there is also a danger of fire with the activated char. Corrosion-resistant construction required, and the fixed bed causes some pressure drop.

References: Rg-12, 13

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Sulfidine

Sponsors: Lurgi

Process description: Sulfur dioxide absorbed in one-to-one mixture of xylidine and water, forming xylidine sulfite. Steam regeneration breaks the sulfite into xylidine and sulfur dioxide.

Absorbing medium: Xylidine and water mixture

End product: Sulfur dioxide

Stage of development: Several plants built in Germany before 1946. Process now discontinued.

Reason for rejection: High loss of xylidine, both to flue gases and as soluble xylidine sulfate, makes the process uneconomic.

References: Rg-1, 6, 8, 19

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Wellman-Lord

Sponsor: Wellman-Lord, Inc.

It is understood that this process will be the subject of a special study to be conducted in the near future.

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Wet Thiogen

Process introduced in early 1900's

Process description: Scrubber effluent treated with barium sulfide to form sulfur and mixture of insoluble barium salts. These are heated to drive off sulfur, then calcined with carbon to reduce salts back to barium sulfide, which is reused.

Absorbing medium: Water

End product: Sulfur

Stage of development: Pilot plant

Reason for rejection: Process fundamentally inefficient, and was abandoned after some pilot plant tests. Low capacity results in large, expensive scrubbers.

References: Rg-1, 6, 19

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Rg-3 Removal of SO_2 from flue gases", Final Report, Contract No. PH 86-67-51, by AVCO Space Systems Division, November 1967.

Rg-4 "Process development in removing sulfur dioxide from hot flue gases (Part 3)", Bureau of Mines Report of Investigations 7021, July 1967.

Rg-5 Private communication.

Rg-6 “Sulfur dioxide: Its chemistry and removal from industrial waste gases”. D. Bienstock et al, Bureau of Mines Information Circular 7836, 1958.

Rg-7 “Economic utilization of sulfur dioxide from metallurgical gases” R.A.King, Ind Eng Chem p 2241-2248, November 1950.

Rg-8 “Recovery of sulfur compounds from atmospheric contaminants”, M. Katz and R. J. Cole, Ind Eng Chem p 2258-2269, November 1950.

Rg-9 “Air pollution: The control of SO_2 from power stacks - Part II” A. M. Squires, Chemical Engineering p 133-140, November 20, 1967.

Rg-10 Chemical & Engineering News, p 11-12, August 14, 1967.

Rg-11 Chemical & Engineering News, p 13, July 8, 1968.

Rg-12 “Air pollution: The control of SO_2 from power stacks - Part III” A.V.Slack. Chemical Engineering, p 188-196 December 4, 1967.

Rg-13 “The Sulfacid process for sulfuric acid” Brit Chem Eng Process Supplement, p 66, November 1967.

Rg-14 Chemical Week, p 57, July 20, 1968

Rg-15 Chemical & Engineering News, p 57, May 13, 1968

Rg-16 “Removing sulfur dioxide from flue gases” S. Katell, Chem Eng Progress p 67, October 1966

Rg-17 Environmental Science & Technology, p 13, January 1967

Rg-18 Chemical Week, p 37, December 30, 1967

Rg-19 "Processes for recovering sulfur from secondary source materials", B.K.Shibler and M.W.Hovey, Bureau of Mines Information Circular 8076, 1962.

Rg-20 "Research must meet the demand for clean air and abundant fuels" J.E. Moody, Combustion, p 20-30, May 1968

Rg-21 "Percolation leaching of manganese ores with sulfur dioxide". F.N.Bender and Carl Rampacek, Bureau of Mines Report of Investigations 5323, March 1957

Rg-22 "Operation of a dithionate-process pilot plant for leaching manganese ore -----" Carl Rampacek et al, Bureau of Mines Report of Investigations 5508, 1959.

Rg-23 "Cost estimates of liquid scrubbing processes for removing sulfur dioxide from flue gases", J.H.Field et al, Bureau of Mines Report of Investigations 5469 1959.

Rg-24 "The molten carbonate process for control of sulfur oxide emission" R.D. Oldenkamp and D.E. McKenzie, North American Rockwell, extract from report under NAPCA contract PH 86-67-128.

Rg-25 "Review of major proposed processes for recovering manganese from United States resources. 3. Sulfur oxide processes". John J. Henn et al, Bureau of Mines Information Circular 8368, 1968.

LIME AND LIMESTONE PROCESS - SCRUBBING AND WASTE-TR

	Units		
Sulfur equivalent in feed gas	tons per day	50	
	1000 tons per year	16.5	
Sulfur oxides in feed gas	volume %	1.0	
Feed gas volume	1000 scfm	77.9	
Capital cost of plant (Ip)		524	

Production Cost Items	Cost Basis		
A. Raw materials			
Feed gas	no cost		
B. Direct costs			
Labor (L)	\$3.75/manhour	15.0	
Supervision (S)	\$4.75/manhour	4.8	
Payroll benefits	25% of (L + S)	5.0	
Steam	allowance	1.0	
Electricity	\$10.0/megawatt-hr	12.4	
Air	allowance	1.0	
Process water	allowance	.5	
Plant water	\$0.02/1000 gal	8.2	
Maintenance materials (M)	3.0% of Ip	15.7	
Factory supplies	0.5% of Ip	2.6	
Laboratory	allowance	.5	
Waste disposal			
a) Lime process	\$1.00/ton	72.0	
b) Limestone process	\$1.00/ton	92.0	
Total direct costs			
a) Lime process (B_1)		138.7	1
b) Limestone process (B_2)		158.7	14
C. Indirect costs			
Depreciation	linear, 15-yr	35.0	
Controllable indirect	0.50 (L + S + M)	17.8	
Noncontrollable indirect	3.0% of Ip	15.7	
Total indirect costs		68.5	
Total operating cost			
a) Lime process	(A + B_1 + C)	207.2	15
b) Limestone process	(A + B_2 + C)	227.2	17

Operating cost, based on sulfur oxides in feed gas	d o l	
Lime process	12.60	
Limestone process	13.80	1

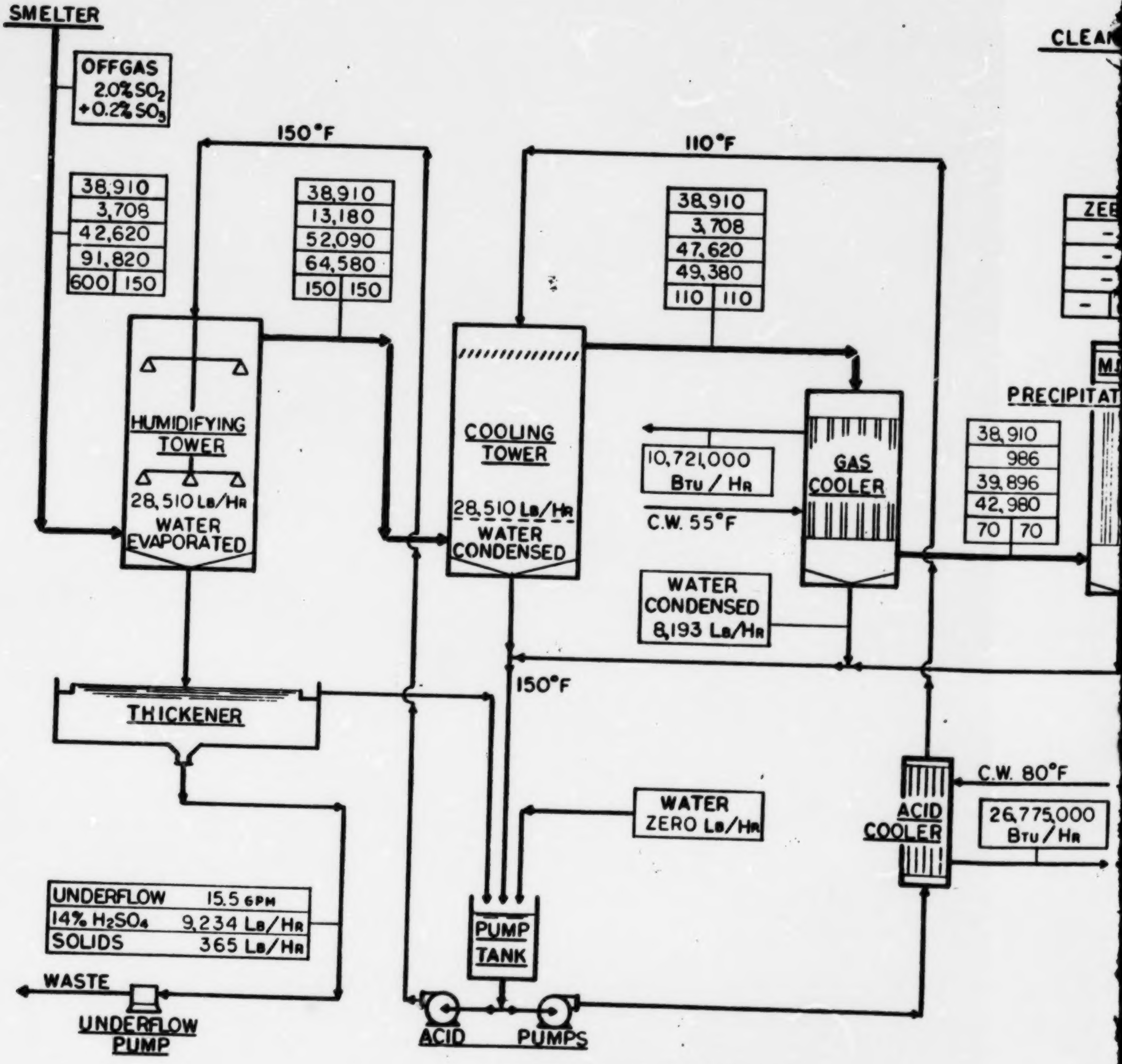
The feed gas has been assumed to be at 600°F and 14.7 psia, with a humidity of 0.05 lb water per lb dry gas. Gas volumes are given in standard cubic feet per minute (scfm) calculated to temperature of 32°F and pressure of one atmosphere. The plant operates 24 hours per day, 330 days per year. No credit is taken for the byproduct calcium sulfite/sulfate, instead a disposal charge is made of \$1

per d
is us
allow
cost.

50	50	50	148	148	148	1,000	1,000	1,000
16.5	16.5	16.5	48.8	48.8	48.8	330	330	330
1.0	4.0	9.0	1.0	4.0	9.0	1.0	4.0	9.0
77.9	19.5	8.7	231.0	57.7	25.6	1,560	390	173
524	169	88	1,218	412	211	6,064	1,921	994
thousands of dollars per year								
15.0	15.0	15.0	15.0	15.0	15.0	30.0	30.0	30.0
4.8	4.8	4.8	4.8	4.8	4.8	9.5	9.5	9.5
5.0	5.0	5.0	5.0	5.0	5.0	9.9	9.9	9.9
1.0	1.0	1.0	1.5	1.5	1.5	5.0	5.0	5.0
12.4	8.6	4.0	43.7	14.8	8.0	343.0	95.6	44.9
1.0	1.0	1.0	1.5	1.5	1.5	5.0	5.0	5.0
.5	.5	.5	.5	.5	.5	3.0	3.0	3.0
8.2	7.4	7.2	24.0	21.8	21.4	162.0	148.0	144.0
15.7	5.1	2.6	36.5	12.4	6.3	181.9	57.6	29.8
2.6	.8	.5	6.1	2.1	1.0	30.3	9.6	5.0
.5	.5	.5	1.0	1.0	1.0	3.0	3.0	3.0
72.0	72.0	72.0	213.0	213.0	213.0	1,440.0	1,440.0	1,440.0
92.0	92.0	92.0	272.0	272.0	272.0	1,835.0	1,835.0	1,835.0
138.7	121.7	114.1	352.6	293.4	279.0	2,222.6	1,816.2	1,729.1
158.7	141.7	134.1	411.6	352.4	338.0	2,617.6	2,211.2	2,124.1
35.0	11.3	5.9	81.2	27.5	14.1	404.5	128.1	66.3
17.8	12.5	11.2	28.2	16.1	13.1	110.7	48.6	34.7
15.7	5.1	2.6	36.5	12.4	6.3	181.9	57.6	29.8
68.5	28.9	19.7	145.9	56.0	33.5	697.1	234.3	130.8
207.2	150.6	133.8	498.5	349.4	312.5	2,919.7	2,050.5	1,859.9
227.2	170.6	153.8	557.5	408.4	371.5	3,314.7	2,445.5	2,254.9
dollars per short ton of sulfur equivalent								
12.60	9.10	8.10	10.20	7.20	6.40	8.80	6.20	5.60
13.80	10.30	9.30	11.40	8.40	7.60	10.00	7.40	6.80

per dry ton. The quantity of waste varies depending on whether lime or limestone is used as the absorbent material. All tons are short tons of 2000 pounds. No allowance was made for contingency or working capital when estimating the capital cost. Utilities were assumed to be available.

B


SMELTER
OFFGAS
2.0% SO2
+0.2% SO3
38,910
3,708
42,620
91,820
600 150
150°F
38,910
13,180
52,090
64,580
150 150
HUMIDIFYING TOWER
28,510 Lb/Hr
WATER EVAPORATED
110°F
38,910
3,708
47,620
49,380
110 110
COOLING TOWER
28,510 Lb/Hr
WATER CONDENSED
10,721,000
Btu / Hr
C.W. 55°F
GAS COOLER
WATER CONDENSED
8,193 Lb/Hr
CLEAN
ZEE
-
-
-
-
MA
PRECIPITAT
38,910
986
39,896
42,980
70 70
150°F
THICKENER
WATER
ZERO Lb/Hr
C.W. 80°F
26,775,000
Btu/Hr
ACID COOLER
UNDERFLOW 15.5 GPM
14% H2SO4 9,234 Lb/Hr
SOLIDS 365 Lb/Hr
WASTE
UNDERFLOW PUMP
PUMP TANK
ACID PUMPS

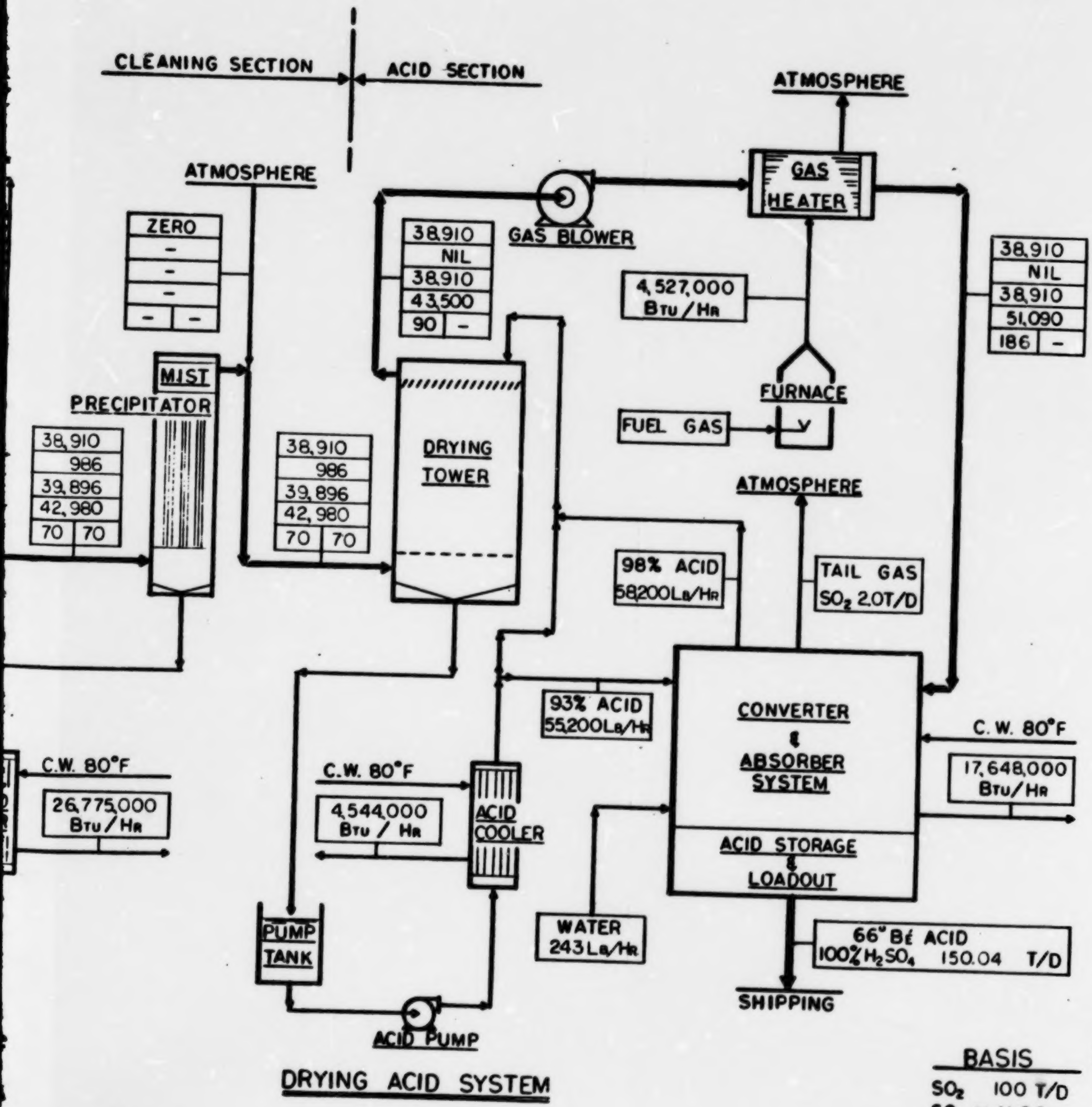
WEAK ACID SYSTEM

SCFM = Cubic Feet per Minute at 32°F & 760mm Hg
Ton = 2000 Lb

KEY

SCFM	DRY GA
SCFM	H_2O
SCFM	TOTAL
ACFM	TOTAL
DB °F	WB °

A


CLEANING SECTION
ACID SECTION
ATMOSPHERE
ZERO
-
-
-
- -
MIST PRECIPITATOR
38,910
986
39,896
42,980
70 70
38,910
986
39,896
42,980
70 70
38,910
NIL
38,910
43,500
90 -
GAS BLOWER
DRYING TOWER
ATMOSPHERE
GAS HEATER
4,527,000 BTU/HR
FURNACE
FUEL GAS
38,910
NIL
38,910
51,090
186 -
ATMOSPHERE
98% ACID 58,200 LB/HR
TAIL GAS SO2 2.0T/D
93% ACID 55,200 LB/HR
CONVERTER & ABSORBER SYSTEM
ACID STORAGE & LOADOUT
C.W. 80°F
17,648,000 BTU/HR
C.W. 80°F
26,775,000 BTU/HR
C.W. 80°F
4,544,000 BTU / HR
ACID COOLER
PUMP TANK
ACID PUMP
WATER 243 LB/HR
66° BÉ ACID 100% H2SO4 150.04 T/D
SHIPPING
DRYING ACID SYSTEM

B

BASIS

SO_2 100 T/D
SO_2 TO H_2SO_4 CONVERSION 98%
TOTAL SULFUR IN OFFGAS 55.08 T/D

KEY

SCFM DRY GAS	
SCFM H_2O	
SCFM TOTAL	
ACFM TOTAL	
DB °F	WB °F

MM HG

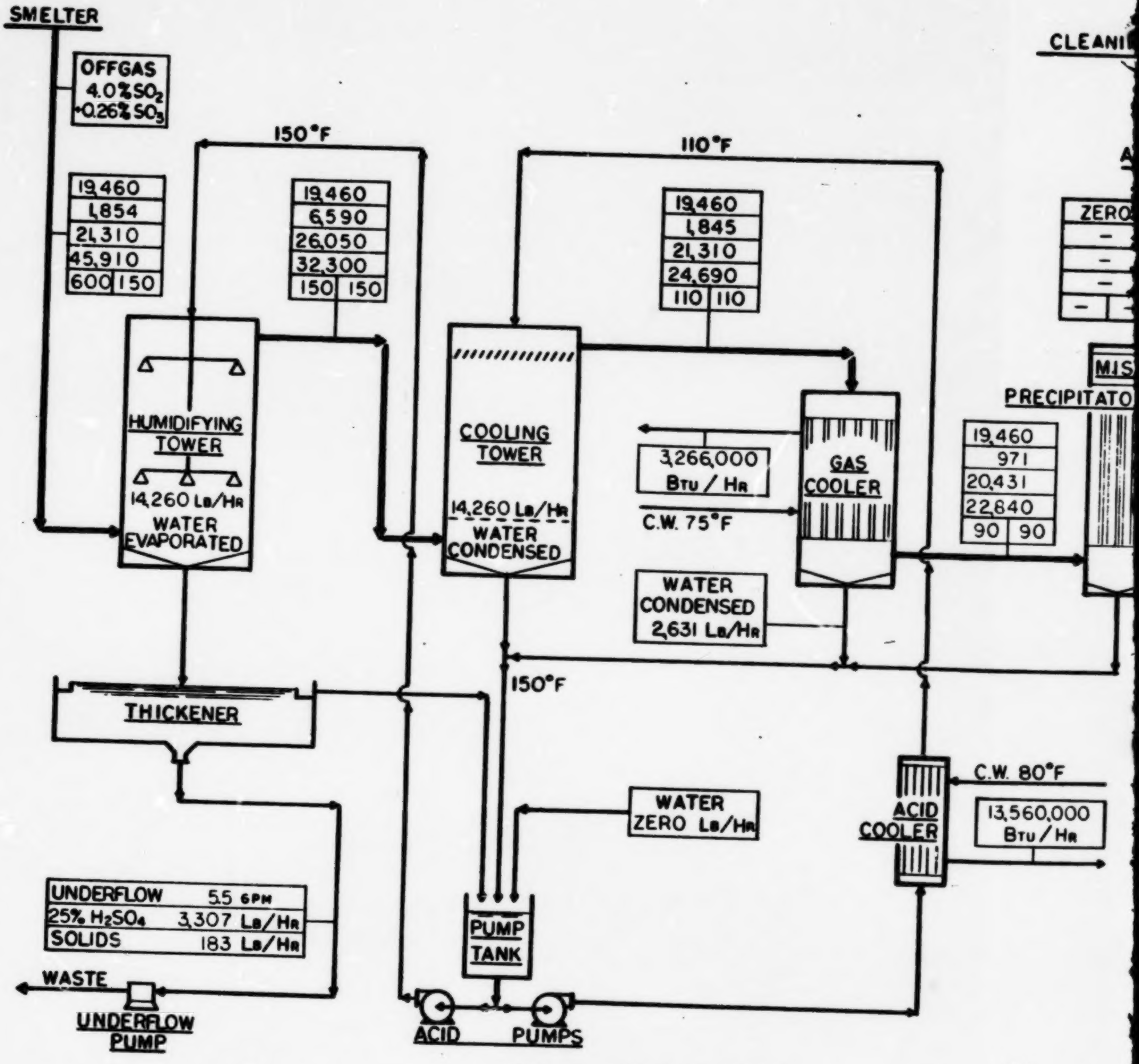
NATIONAL AIR POLLUTION CONTROL ADMINISTRATION

2% SO_2 IN OFFGAS SULFURIC ACID PROCESS FLOW DIAGRAM

ARTHUR G. McKEE & COMPANY
WESTERN KNAPP ENGINEERING DIVISION
SAN FRANCISCO CALIFORNIA

ENG. DEPT. DWG. 10-02-001

PLATE NO. B-1

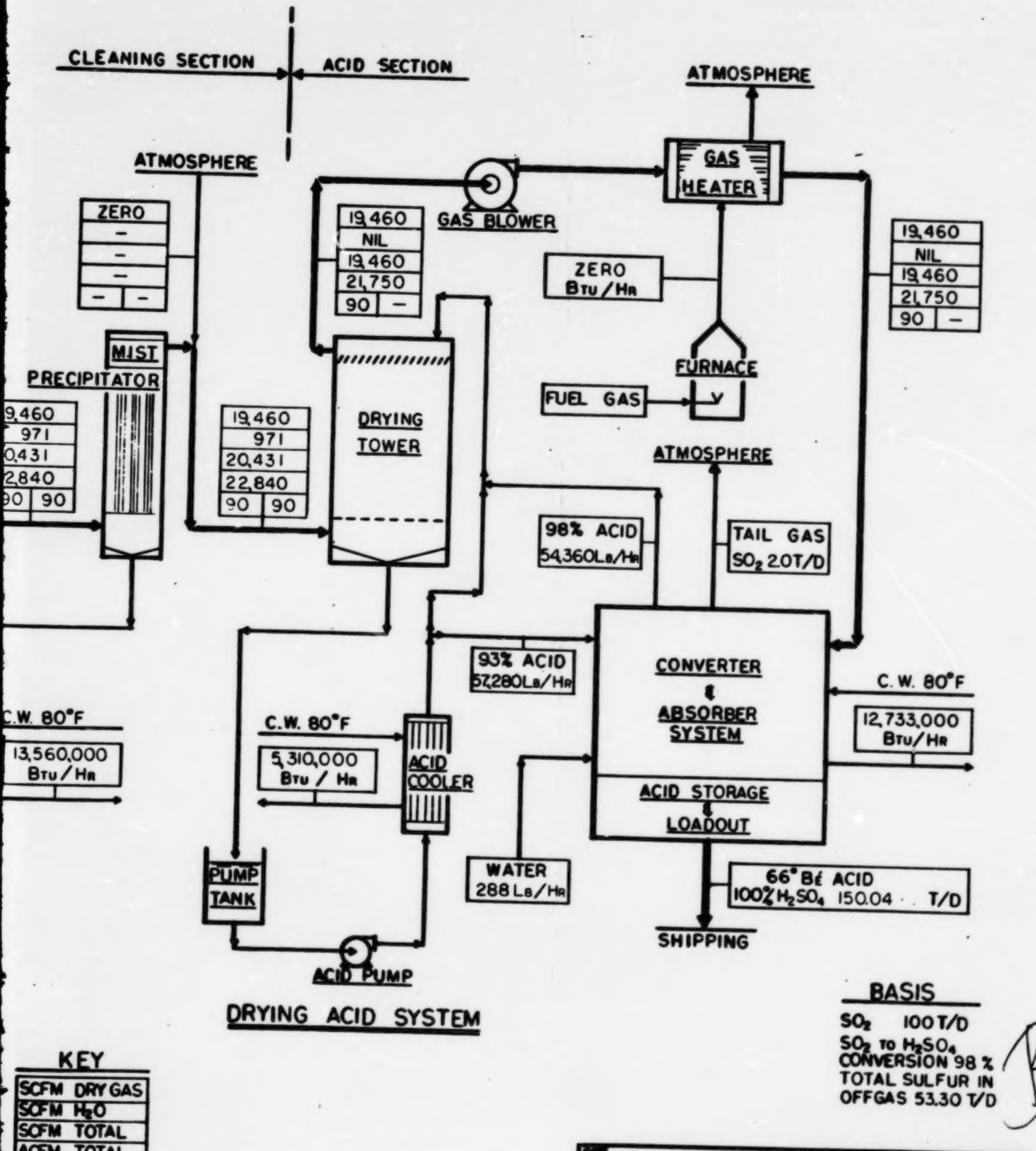

SMELTER
OFFGAS
4.0% SO2
+0.26% SO3
19,460
1,854
21,310
45,910
600 | 150
150°F
19,460
6,590
26,050
32,300
150 | 150
HUMIDIFYING TOWER
14,260 Lb/Hr
WATER EVAPORATED
110°F
19,460
1,845
21,310
24,690
110 | 110
COOLING TOWER
14,260 Lb/Hr
WATER CONDENSED
3,266,000
Btu / Hr
C.W. 75°F
GAS COOLER
WATER CONDENSED
2,631 Lb/Hr
CLEANI
ZERO
MIS
PRECIPITATO
19,460
971
20,431
22,840
90 | 90
150°F
THICKENER
WATER
ZERO Lb/Hr
C.W. 80°F
ACID COOLER
13,560,000
Btu / Hr
UNDERFLOW 5.5 GPM
25% H2SO4 3,307 Lb/Hr
SOLIDS 183 Lb/Hr
WASTE
UNDERFLOW PUMP
PUMP TANK
ACID PUMPS

WEAK ACID SYSTEM

SCFM = Cubic Feet per Minute at 32°F & 760mm Hg
Ton = 2000 Lb

KEY

SCFM DRY GAS	
SCFM H_2O	
SCFM TOTAL	
ACFM TOTAL	
DB °F	WB °F


CLEANING SECTION
ACID SECTION
ATMOSPHERE
ATMOSPHERE
ATMOSPHERE
ZERO
—
—
—
— | —
MIST
PRECIPITATOR
9,460
971
0,431
2,840
90 | 90
19,460
971
20,431
22,840
90 | 90
19,460
NIL
19,460
21,750
90 | —
GAS BLOWER
GAS HEATER
DRYING TOWER
ZERO Btu/Hr
FURNACE
FUEL GAS
19,460
NIL
19,460
21,750
90 | —
98% ACID 54,360 Lb/Hr
TAIL GAS SO2 2.0 T/D
93% ACID 57,280 Lb/Hr
CONVERTER & ABSORBER SYSTEM
ACID STORAGE & LOADOUT
C.W. 80°F
12,733,000 Btu/Hr
C.W. 80°F
13,560,000 Btu/Hr
C.W. 80°F
5,310,000 Btu/Hr
ACID COOLER
PUMP TANK
ACID PUMP
WATER 288 Lb/Hr
66° Bé ACID 100% H2SO4 150.04 T/D
SHIPPING
DRYING ACID SYSTEM

KEY

SCFM DRY GAS	
SCFM H_2O	
SCFM TOTAL	
ACFM TOTAL	
DB °F	WB °F

BASIS

SO_2 100 T/D
SO_2 TO H_2SO_4 CONVERSION 98 %
TOTAL SULFUR IN OFFGAS 53.30 T/D

B

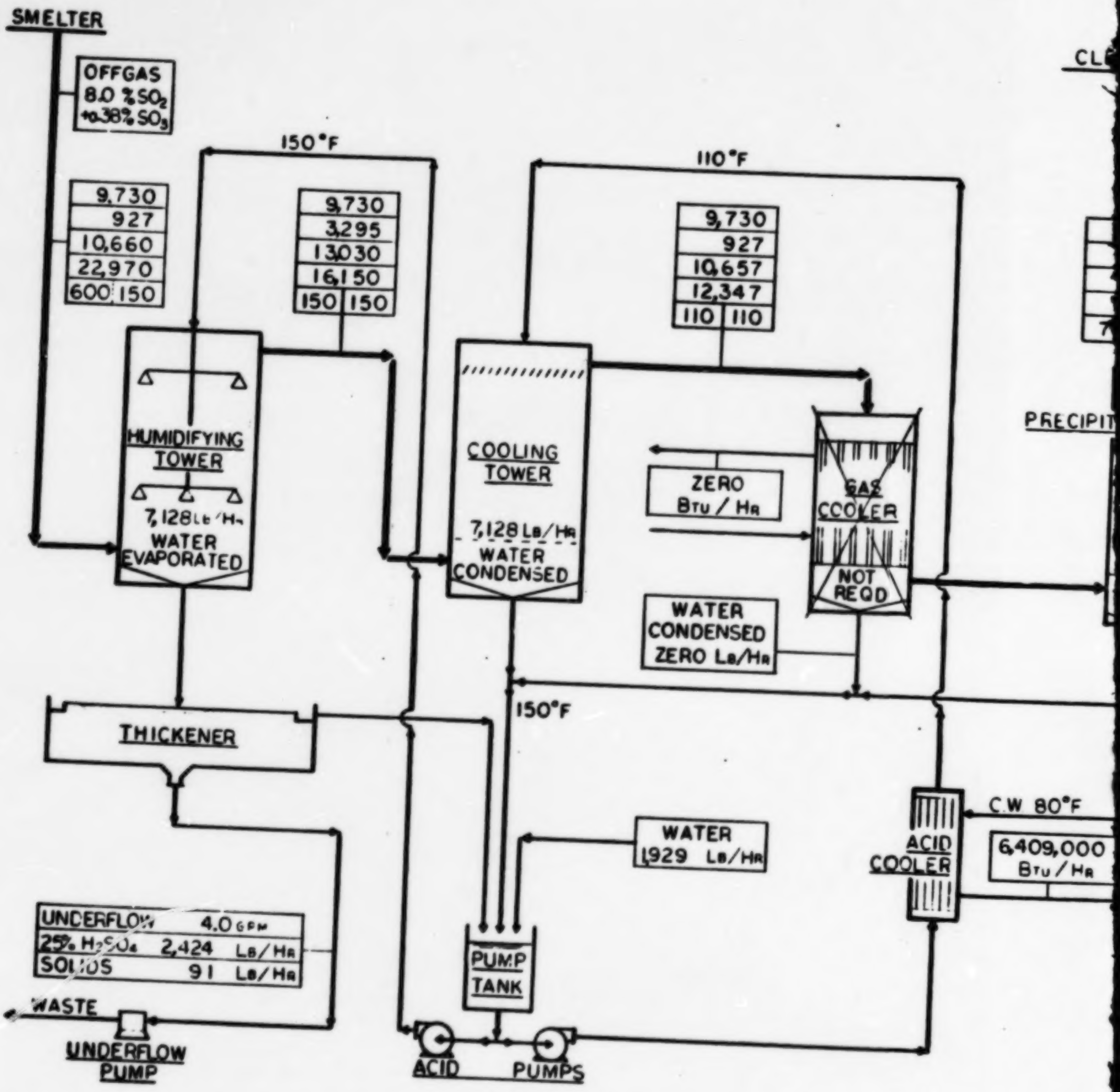
NATIONAL AIR POLLUTION CONTROL ADMINISTRATION

4% SO_2 IN OFFGAS
SULFURIC ACID PROCESS
FLOW DIAGRAM

ARTHUR G. McKEE & COMPANY
WESTERN KNAPP ENGINEERING DIVISION
SAN FRANCISCO CALIFORNIA

ENG. DEPT. DWG. 10-02-002

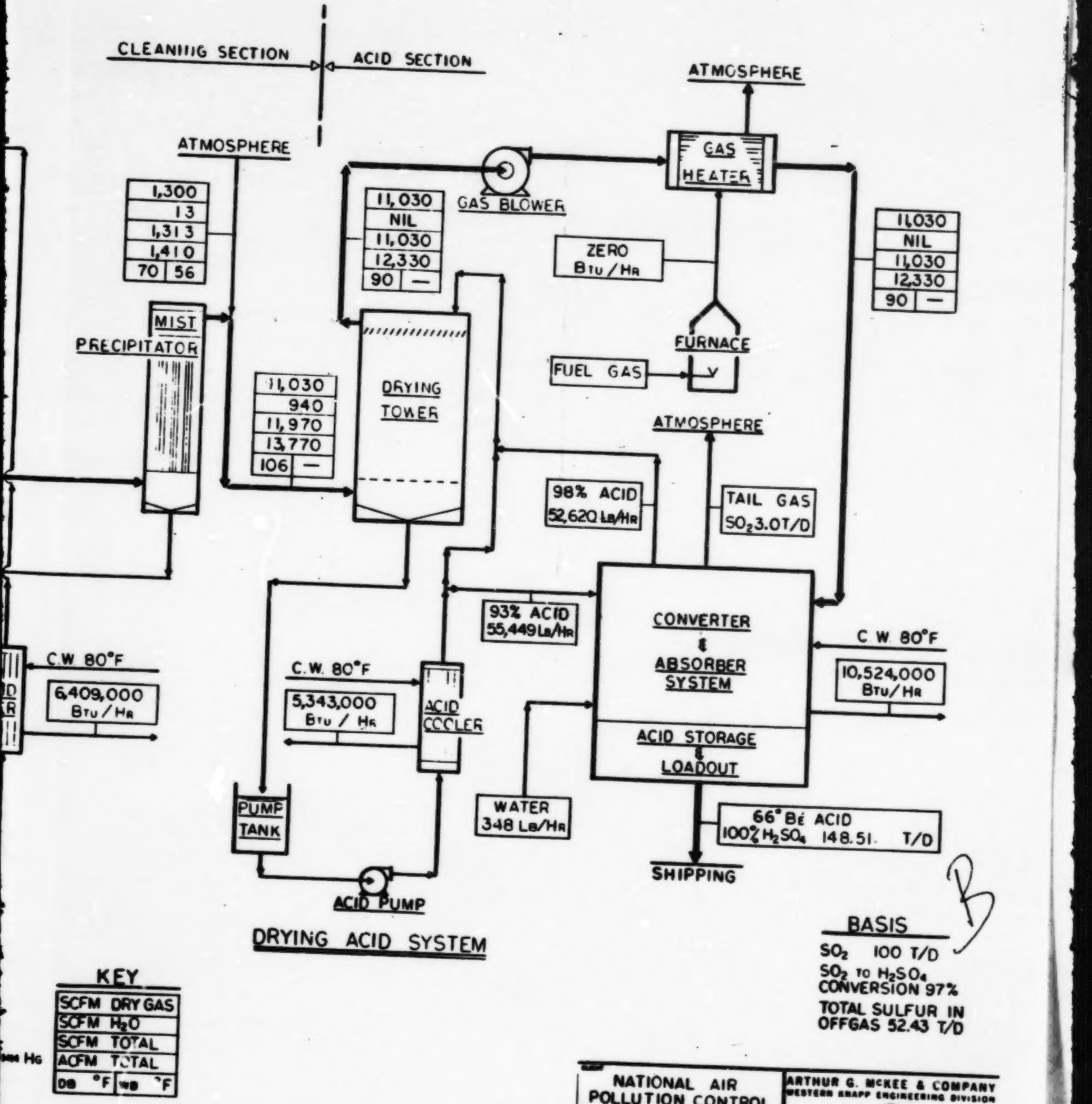
PLATE NO. B.2


SMELTER
OFFGAS
8.0 % SO₂
+0.38% SO₃
150°F
9,730
927
10,660
22,970
600 150
9,730
3,295
13,030
16,150
150 150
HUMIDIFYING TOWER
7,128 Lb/Hr
WATER EVAPORATED
110°F
9,730
927
10,657
12,347
110 110
COOLING TOWER
7,128 Lb/Hr
WATER CONDENSED
ZERO
Btu / Hr
GAS COOLER
NOT REQD
WATER CONDENSED
ZERO Lb/Hr
CL
PRECIPIT
7
THICKENER
150°F
WATER
1929 Lb/Hr
C.W 80°F
6,409,000
Btu / Hr
ACID COOLER
UNDERFLOW 4.0 GPM
25% H₂SO₄ 2,424 Lb/Hr
SOLIDS 91 Lb/Hr
WASTE
UNDERFLOW PUMP
PUMP TANK
ACID
PUMPS

WEAK ACID SYSTEM

KEY
SCFM DRY G
SCFM H_2O
SCFM TOTA
ACFM TOTA
DB °F | WB

SCFM = Cubic Feet per Minute at 32°F & 760mm Hg
Ton = 2000 Lb


CLEANING SECTION
ACID SECTION
ATMOSPHERE
1,300
13
1,313
1,410
70 | 56
MIST PRECIPITATOR
11,030
940
11,970
13,770
106 | —
11,030
NIL
11,030
12,330
90 | —
GAS BLOWER
DRYING TOWER
ATMOSPHERE
GAS HEATER
ZERO Btu/Hr
FURNACE
FUEL GAS
11,030
NIL
11,030
12,330
90 | —
ATMOSPHERE
98% ACID 52,620 Lb/Hr
TAIL GAS SO_2 3.0 T/D
93% ACID 55,449 Lb/Hr
CONVERTER & ABSORBER SYSTEM
ACID STORAGE & LOADOUT
C.W. 80°F
10,524,000 Btu/Hr
C.W. 80°F
6,409,000 Btu/Hr
C.W. 80°F
5,343,000 Btu/Hr
ACID COOLER
WATER 348 Lb/Hr
66° Bé ACID 100% H_2SO_4 148.51. T/D
SHIPPING
PUMP TANK
ACID PUMP
DRYING ACID SYSTEM
KEY
SCFM DRY GAS
SCFM H_2O
SCFM TOTAL
ACFM TOTAL
DB °F | WB °F
Hg
BASIS
SO_2 100 T/D
SO_2 to H_2SO_4 CONVERSION 97%
TOTAL SULFUR IN OFFGAS 52.43 T/D

B

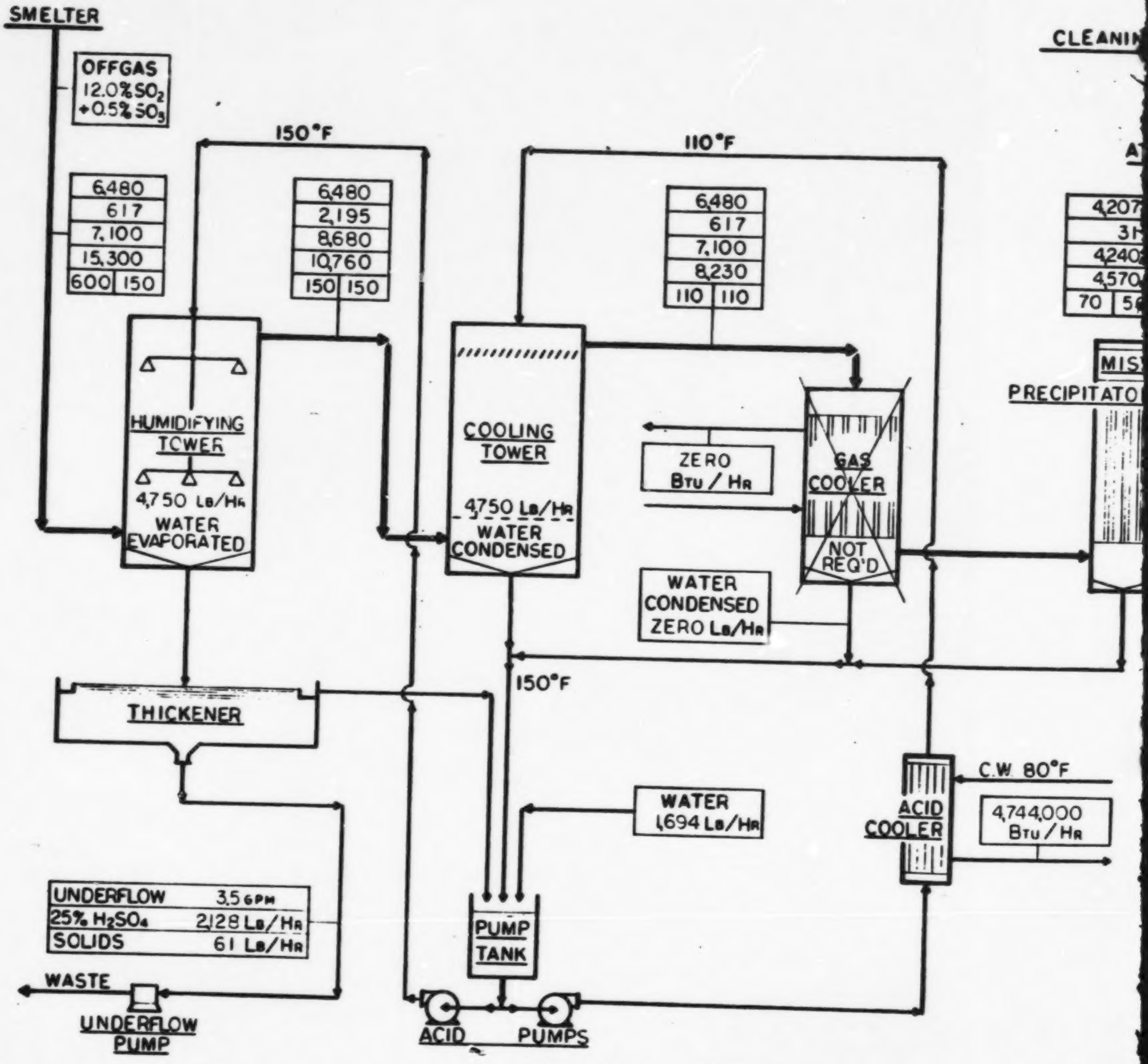
NATIONAL AIR
POLLUTION CONTROL
ADMINISTRATION

8% SO_2 IN OFFGAS
SULFURIC ACID PROCESS
FLOW DIAGRAM

ARTHUR G. McKEE & COMPANY
WESTERN KNAPP ENGINEERING DIVISION
SAN FRANCISCO CALIFORNIA

ENG. DEPT. DWG. 10-02-003

PLATE NO. B-3


SMELTER
OFFGAS 12.0% SO2 +0.5% SO3
6,480
617
7,100
15,300
600 150
150°F
6,480
2,195
8,680
10,760
150 150
HUMIDIFYING TOWER
4,750 Lb/Hr WATER EVAPORATED
110°F
6,480
617
7,100
8,230
110 110
COOLING TOWER
4,750 Lb/Hr WATER CONDENSED
ZERO Btu / Hr
GAS COOLER
NOT REQ'D
WATER CONDENSED ZERO Lb/Hr
CLEANIN
4,207
3
4,240
4,570
70 5
MIS
PRECIPITATO
150°F
THICKENER
WATER 1,694 Lb/Hr
C.W. 80°F
ACID COOLER
4,744,000 Btu / Hr
UNDERFLOW 3.5 GPM
25% H2SO4 2,128 Lb/Hr
SOLIDS 61 Lb/Hr
WASTE
UNDERFLOW PUMP
PUMP TANK
ACID PUMPS

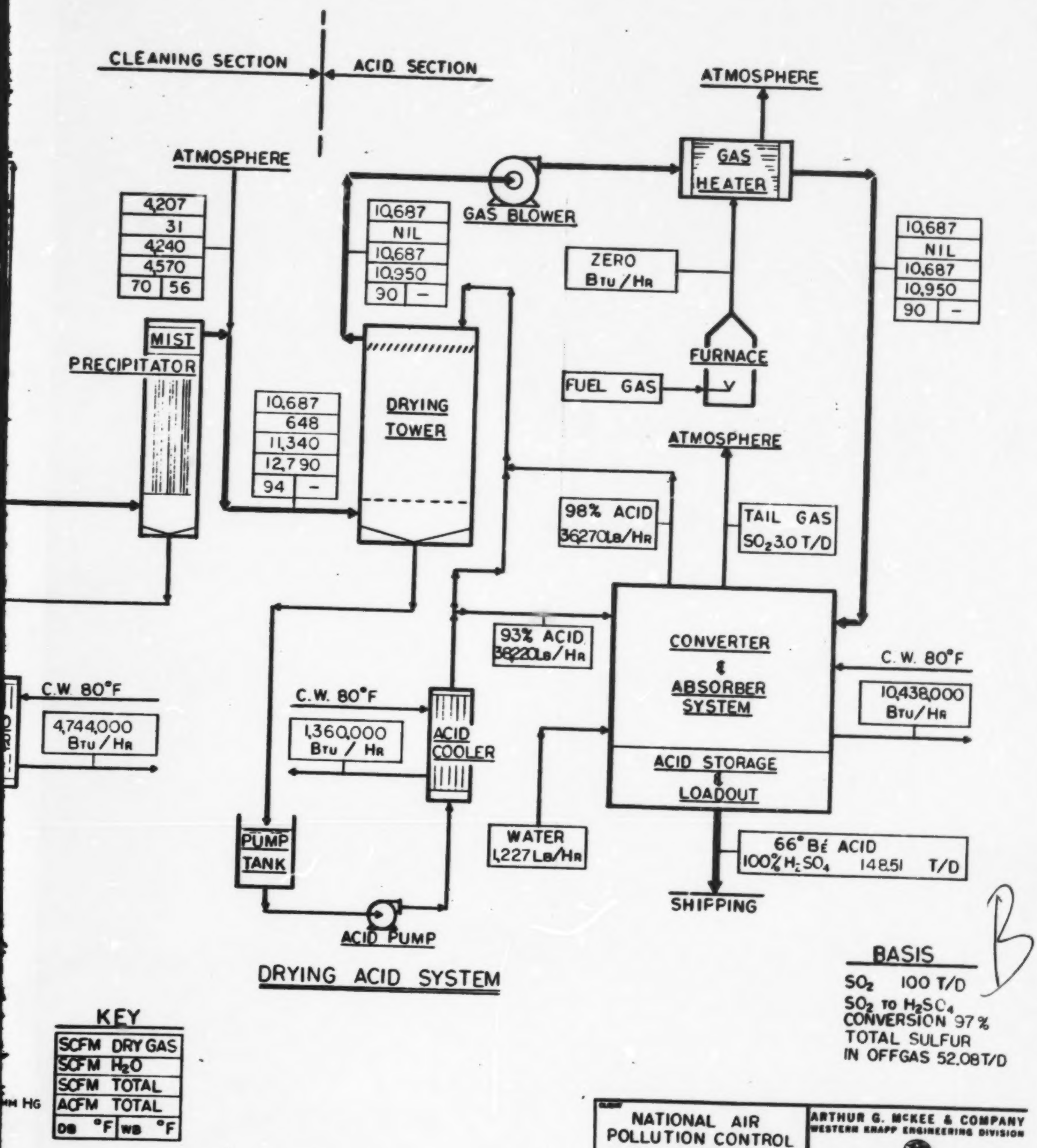
WEAK ACID SYSTEM

KEY

SCFM DRY GAS
SCFM H_2O
SCFM TOTAL
ACFM TOTAL
DB °F | WB °F

SCFM = Cubic Feet per Minute at 32°F & 760mm Hg
Ton = 2000 Lb

A


CLEANING SECTION
ACID SECTION
ATMOSPHERE
4,207
31
4,240
4,570
70 | 56
MIST PRECIPITATOR
10,687
NIL
10,687
10,950
90 | -
GAS BLOWER
ATMOSPHERE
GAS HEATER
10,687
NIL
10,687
10,950
90 | -
ZERO BTU/HR
FURNACE
FUEL GAS
10,687
648
11,340
12,790
94 | -
DRYING TOWER
ATMOSPHERE
98% ACID 36270 LB/HR
TAIL GAS SO2 3.0 T/D
93% ACID 38220 LB/HR
CONVERTER & ABSORBER SYSTEM
ACID STORAGE & LOADOUT
C.W. 80°F
10,438,000 BTU/HR
C.W. 80°F
4,744,000 BTU/HR
C.W. 80°F
1,360,000 BTU/HR
ACID COOLER
WATER 1,227 LB/HR
66° Bé ACID 100% H2SO4 148.51 T/D
SHIPPING
PUMP TANK
ACID PUMP
DRYING ACID SYSTEM
KEY
SCFM DRY GAS
SCFM H2O
SCFM TOTAL
ACFM TOTAL
DB °F | WB °F
MM HG
BASIS
SO2 100 T/D
SO2 TO H2SO4 CONVERSION 97%
TOTAL SULFUR IN OFFGAS 52.08 T/D

B

NATIONAL AIR
POLLUTION CONTROL
ADMINISTRATION

12% SO_2 IN OFFGAS
SULFURIC ACID PROCESS
FLOW DIAGRAM

ARTHUR G. McKEE & COMPANY
WESTERN KNAPP ENGINEERING DIVISION
SAN FRANCISCO CALIFORNIA

ENG. DEPT. DWG. 10-02-004

PLATE NO. B-4

SULFURIC ACID - CAPITAL COST ESTIMATES

Sulfur dioxide in smelter offgas, percent by volume, dry basis	2.0	4.0	
Sulfur dioxide in offgas, tons per day	53.97	107.9	
Acid produced at 66° Baume, tons per day of equivalent 100% H_2SO_4	81.0	161.9	
Cleaning section, $	842,000	792,000	792,
Acid section, $	1,233,000	1,293,000	1,283,
Cooling water section, $	165,000	155,000	145,
Total acid plant, $	2,240,000	2,240,000	2,220,

The $2,220,000 cost of a plant to handle offgas with 5% sulfur dioxide is the result of a detailed estimate of a conventional contact sulfuric acid plant with the necessary pretreatment section for smelter offgases. The same plant, with modifications, will handle 2 to 12% offgas with quantities and costs as shown here. The curves of Figure VIII b-1 were drawn from these estimates using slopes of 0.8 to show the relation of capital cost to tons of sulfur dioxide per day.

These capita
capital, cos
offsite uti
access, or e
of the gas t
grain per st

SULFURIC ACID - CAPITAL COST ESTIMATES

er offgas, y basis	2.0	4.0	5.0	8.0	12.0
s,	53.97	107.9	135	190.4	196.5
ume, tons 100% H_2SO_4	81.0	161.9	200	282.0	291.8
	842,000	792,000	792,000	707,000	592,000
	1,233,000	1,293,000	1,283,000	1,288,000	1,273,000
s	165,000	155,000	145,000	150,000	140,000
	2,240,000	2,240,000	2,220,000	2,145,000	2,005,000

plant to handle offgas
s the result of a detailed
al contact sulfuric acid
pretreatment section for
ame plant, with modifications,
gas with quantities and
e curves of Figure VIII b-1
timates using slopes of 0.8
capital cost to tons of

These capital costs do not include working capital, cost of land, inventory, interest, offsite utilities, steam generators, plant access, or equipment for preliminary cleaning of the gas to reduce the dust content to 0.1 grain per standard cubic foot.

B

SULFURIC ACID -

	Units			
Sulfur dioxide in feed gas	% by volume, dry	2.	2.	
	tons per day	54.	110.	
Sulfur trioxide in feed gas	% by volume, dry	.2	.2	
Feed gas volume, dry	1000 scfm	21.0	42.8	
wet	1000 scfm	23.0	46.9	
Total sulfur equivalent in feed gas	tons per day	29.7	60.5	
	1000 tons per year	9.8	20.0	
Efficiency of conversion, SO_2 to H_2SO_4	percent	98.	98.	
Byproducts				
66° Baume acid (100% H_2SO_4 basis),	1000 ton/yr	26.7	54.5	
(sulfur equivalent basis),	1000 ton/yr	8.7	17.8	
Weak acid (100% H_2SO_4 basis),	1000 ton/yr	2.7	5.6	
Capital cost of plant (Ip)	$ millions	2.24	4.0	

Production Cost Items	Cost Basis			
A. Raw materials				
Waste gas	no cost			
B. Direct costs				
Labor (L)	$3.75/manhour	60.0	60.0	
Supervision (S)	$4.75/manhour	4.8	4.8	
Payroll benefits	25% of (L + S)	16.2	16.2	
Steam	$0.80 per 1000 lb	76.0	155.2	2
Electricity	$10.0 per megawatt-hr	77.0	157.0	2
Water	$0.20 per 1000 gal	5.0	10.3	
Fuel: Natural gas	$0.40 per million Btu	7.6	15.8	
Maintenance materials (M)	3.0% of Ip	67.2	120.0	1
Factory supplies	0.5% of Ip	11.2	20.0	
Waste acid disposal	$0.50 per 1000 gal	2.0	4.0	
Total direct costs		327.0	563.3	8
C. Indirect costs				
Depreciation	Linear, 15-yr	149.3	266.7	40
Controllable indirect	0.50 (L + S + M)	66.0	92.4	12
Noncontrollable indirect	3.0% of Ip	67.2	120.0	18
Total indirect costs		282.5	479.1	70
Total operating cost fob plantsite	(A + B + C)	609.5	1,042.4	1,56
Operating cost, 66° Baume acid (100% H_2SO_4 basis)		22.80	19.10	1
sulfur equivalent in feed gas		62.20	52.10	4

Gas flows (scfm) are converted to standard conditions: Temperature 32°F and pressure of one atmosphere. All tons are short tons of 2000 pounds. No credit is taken for value of byproducts.

The sulfuric acid produced i
strength, but the table give
amounts of 100 percent acid.

Costs include stor
loadout via tank c
indirect costs inc
overhead and superv
include local taxes

A

URIC ACID - OPERATING COST ESTIMATES

Appendix B
Table B -2

2.	2.	4.	4.	4.	8.0	8.0	8.0	12.	12.	12.
110.	180.	107.9	218.	360.	190.4	410.	680.	196.5	460.	760.
.2	.2	.26	.26	.26	.38	.38	.38	.5	.5	.5
42.8	70.0	21.0	42.4	70.1	18.5	39.9	66.2	12.7	29.8	49.2
46.9	76.7	23.0	46.5	76.7	19.3	43.7	72.5	13.9	32.6	53.9
60.5	99.0	57.5	116.1	192.0	99.7	215.0	356.7	102.1	239.5	395.4
20.0	32.7	19.0	38.3	63.4	32.9	71.0	117.7	33.7	79.0	130.5
98.	98.	98.	98.	98.	97.	97.	97.	97.	97.	97.
54.5	89.1	53.4	107.9	178.2	93.3	200.9	333.2	96.3	225.4	372.5
17.8	29.1	17.5	35.3	58.3	30.8	66.4	110.2	31.7	74.4	122.8
5.6	9.1	3.5	7.2	11.8	4.6	9.8	16.3	4.1	9.7	16.0
4.0	6.0	2.24	4.0	6.0	2.145	4.0	6.0	2.005	4.0	6.0

thousands of dollars per year

60.0	60.0	60.0	60.0	75.0	60.0	90.0	105.0	60.0	90.0	120.0
4.8	9.5	4.8	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5
16.2	17.4	16.2	17.4	21.1	17.4	24.9	28.6	17.4	24.9	32.4
155.2	253.4	46.6	93.9	155.2						
157.0	257.0	77.0	156.0	257.0	72.0	154.0	256.0	66.0	155.0	257.0
10.3	16.8	6.5	13.2	21.8	8.9	19.1	31.7	7.4	17.4	28.7
15.8	25.6	1.0	1.0	2.0	1.0	1.0	2.0	1.0	1.0	2.0
120.0	180.0	67.2	120.0	180.0	64.4	120.0	180.0	60.2	120.0	180.0
20.0	30.0	11.2	20.0	30.0	10.7	20.0	30.0	10.0	20.0	30.0
4.0	6.6	1.4	2.8	4.7	1.8	3.9	6.4	1.6	3.8	6.3
563.3	856.3	291.9	493.8	756.3	245.7	442.4	649.2	233.1	441.6	665.9
266.7	400.0	149.3	266.7	400.0	143.0	266.7	400.0	133.7	266.7	400.0
92.4	124.8	66.0	94.8	132.2	67.0	109.8	147.2	64.8	109.8	154.8
120.0	180.0	67.2	120.0	180.0	64.4	120.0	180.0	60.2	120.0	180.0
479.1	704.8	282.5	481.5	712.2	274.4	496.5	727.2	258.7	496.5	734.8
042.4	1,561.1	574.4	975.3	1,468.5	520.1	938.9	1,376.4	491.8	938.1	1,400.7

dollars per short ton

19.10	17.50	10.80	9.00	8.20	5.60	4.70	4.10	5.10	4.20	3.80
52.10	47.70	30.20	25.50	23.20	15.80	13.20	11.70	14.60	11.90	10.70

id produced is 66° Baume (93.2 percent)
he table gives weights of equivalent
percent acid.

include storage of the product acid and
t via tank car or truck. Controllable
ct costs include maintenance labor, laboratory,
ead and supervision. Noncontrollable indirects
de local taxes and insurance.

The plant operates 24 hours per day, 330 days per year. Sulfur trioxide in the feed gas is recovered as weak acid.

B

COMINCO ABSORPTION PROCESS

Feed Gas Conditions

Sulfur dioxide, percent by volume	0.5	0.5	0.5	0.5	1	1
tons per day	20.	40.	80.	160.	20.	40
Sulfur trioxide, percent by volume	.05	.05	.05	.05	.1	.1
Feed gas volume, 1000 scfm	31.2	62.3	125.	249.	15.6	31.2
Total sulfur equivalent, tons per day	11.0	22.0	44.0	88.1	11.0	22.0
1000 tons/year	3.63	7.27	14.5	29.1	3.63	7.27

Capital Costs

Costs i

A. Ammonia Transfer & Storage						
Installed equipment cost	40	40	50	71	40	40
Plant cost (factor 2.5)	99	99	125	178	99	99
B. Scrubber Section						
Installed equipment cost	743	1,390	2,587	4,832	398	743
Plant cost (factor 4.2)	3,122	5,838	10,864	20,293	1,670	3,122
C. Stripper Section						
Installed equipment	48	84	146	253	48	84
Plant cost (factor 3.4)	164	284	495	862	164	284
D. Crystallizer & Product Section						
Installed equipment cost	198	321	520	847	198	321
Plant cost (factor 4.0)	792	1,283	2,080	3,389	792	1,283
Total Plant Cost (A + B + C + D)	4,177	7,504	13,564	24,722	2,725	4,788
(Rounded)	4,180	7,500	13,600	24,700	2,720	4,800

These are estimated costs for the battery limits plant. Costs for a cooling tower are included, but otherwise these costs do not include offsite utilities, contingencies,

Appendix B
Table B - 3

ON PROCESS - CAPITAL COST ESTIMATES

	1	1	1	2	2	2	2	3	3	3	3
	40	80	160	20	40	80	160	20	40	80	160
1	.1	.1	.1	.2	.2	.2	.2	.23	.23	.23	.23
6	31.2	62.3	125.	7.8	15.6	31.2	62.3	5.2	10.4	20.8	41.5
0	22.0	44.0	88.1	11.0	22.0	44.0	88.1	10.8	21.6	43.1	86.2
63	7.27	14.5	29.1	3.63	7.27	14.5	29.1	3.56	7.11	14.2	28.5

osts in thousands of dollars

40 99	50 125	71 178	40 99	40 99	50 125	71 178	40 99	40 99	50 125	71 178
743 3,122	1,390 5,838	2,587 10,864	213 896	398 1,670	743 3,122	1,390 5,838	148 621	267 1,121	517 2,170	963 4,046
84 284	146 495	253 862	48 164	84 284	146 495	253 862	48 164	84 284	146 495	253 862
321 1,283	520 2,080	847 3,389	198 792	321 1,283	520 2,080	847 3,389	198 792	321 1,283	520 2,080	847 3,389
4,788	8,538	15,293	1,951	3,336	5,822	10,267	1,676	2,787	4,870	8,475
4,800	8,500	15,300	2,000	3,300	5,800	10,300	1,700	2.800	4,900	8,500

tery
wer
ts do
gencies,

working capital, inventory, interest, cost of land, plant access, or equipment for removal of the bulk of entrained solids from the smelter offgas.

B

COMINCO ABSORPTION PROCESS

Operating Conditions							
Sulfur dioxide in feed gas	percent by volume	0.5	0.5	0.5	0.5	1.0	1.0
	tons per day	20.	40.	80.	160.	20.	40.
Sulfur trioxide in feed gas	percent by volume	.05	.05	.05	.05	.1	.1
Feed gas volume, dry	1000 scfm	31.2	62.3	124.6	249.2	15.6	31.2
Total sulfur equivalent in feed gas	tons per day	11.0	22.0	44.0	88.1	11.0	22.0
	1000 tons per year	3.63	7.3	14.5	29.0	3.63	7.3
Total sulfur equivalent recovered (95%)	1000 tons per year	3.45	6.9	13.8	27.6	3.45	6.9
Capital cost of plant (Ip)	$, thousands	4,177.	7,504.	13,564.	24,722.	2,725.	4,788.

Operating Cost Items	Cost Basis						t h
A. Raw materials							
Feed gas	no cost						
Anhydrous ammonia	$50/ton	111.1	222.2	444.4	888.8	111.1	222.2
Sulfuric acid (100% basis)	$7/ton	44.8	89.6	179.2	358.3	44.8	89.6
Total raw materials		155.9	311.8	623.6	1,247.1	155.9	311.8
B. Direct costs							
Labor (L)	$3.75/manhour	80.0	80.0	90.0	130.0	80.0	80.0
Supervision (S)	$4.75/manhour	9.5	9.5	9.5	19.0	9.5	9.5
Payroll benefits	25% of (L + S)	22.4	22.4	24.9	37.2	22.4	22.4
Steam	$0.80/1000 lb	15.8	31.7	63.4	126.7	15.8	31.7
Electricity	$10.0/megawatt-hr	35.4	70.8	141.6	283.2	23.6	47.2
Plant air	allowance	2.0	3.5	5.0	8.0	2.0	3.5
Process water	allowance	.5	1.0	1.5	2.0	.5	1.0
Plant water	$0.02/1000 gal	85.5	171.0	342.0	684.0	47.5	95.0
Fuel	$0.40/million Btu	2.4	4.8	9.5	19.0	2.4	4.8
Maintenance materials (M)	3.0% of Ip	126.0	225.0	408.0	741.0	81.9	143.7
Factory supplies	0.5% of Ip	21.0	37.5	68.0	123.5	13.7	24.0
Total direct costs		400.5	657.2	1,163.4	2,173.6	299.3	462.8
C. Indirect costs							
Depreciation	linear, 15 years	280.0	500.0	907.1	1,647.5	182.1	319.5
Controllable indirect	0.50 (L + S + M)	107.8	157.2	253.8	445.0	85.7	116.6
Noncontrollable indirect	3.0% of Ip	126.0	225.0	408.0	741.0	81.9	143.7
Total indirect costs		513.8	882.2	1,568.9	2,833.5	349.7	579.8
Total gross operating cost	(A + B + C)	1,070.2	1,851.2	3,355.9	6,254.2	804.9	1,354.4
					dollars		per s
Gross operating cost	(95% recovery of total sulfur)	310.	268.	243.	227.	233.	196.
Byproducts (See text for yields assumed)							
Ammonium sulfate	1000 tons/year	8.2	16.4	32.8	65.5	8.2	16.4
Sulfur dioxide	1000 tons/year	6.3	12.5	25.1	50.2	6.3	12.5
Sulfuric acid, 10 to 30%	1000 tons/year (100% basis)	1.0	2.0	4.0	8.1	1.0	2.0

Gas flows (scfm) are at standard conditions:
temperature 32°F and pressure of one atmosphere. All tons are short tons of 2000 pounds. No credit is taken for value of byproducts.

The plan
330 days

Appendix B
Table B-4

INCO ABSORPTION PROCESS - OPERATING COST ESTIMATE

0.5	1.0	1.0	1.0	1.0	2.	2.	2.	2.	3.	3.	3.	3.
60.	20.	40.	80.	160.	20.	40.	80.	160.	20.	40.	80.	160.
.05	.1	.1	.1	.1	.2	.2	.2	.2	.23	.23	.23	.23
49.2	15.6	31.2	62.3	124.5	7.8	15.6	31.2	62.3	5.19	10.4	20.8	41.5
38.1	11.0	22.0	44.0	88.1	11.0	22.0	44.0	88.1	10.8	21.6	43.1	86.2
29.0	3.63	7.3	14.5	29.1	3.63	7.3	14.5	29.0	3.56	7.1	14.2	28.5
27.6	3.45	6.9	13.8	27.6	3.45	6.9	13.8	27.6	3.38	6.76	13.5	27.0
22.	2,725.	4,788.	8,538.	15,293.	1,951.	3,336.	5,822.	10,267.	1,676.	2,787.	4,870.	8,475.
thousands of dollars per year												
88.8	111.1	222.2	444.4	888.8	111.1	222.2	444.4	888.8	111.1	222.2	444.4	888.8
58.3	44.8	89.6	179.2	358.3	44.8	89.6	179.2	358.3	44.8	89.6	179.2	358.3
47.1	155.9	311.8	623.6	1,247.1	155.9	311.8	623.6	1,247.1	155.9	311.8	623.6	1,247.1
0.0	80.0	80.0	90.0	100.0	80.0	80.0	90.0	100.0	80.0	80.0	90.0	100.0
9.0	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5
87.2	22.4	22.4	24.9	27.4	22.4	22.4	24.9	27.4	22.4	22.4	24.9	27.4
26.7	15.8	31.7	63.4	126.7	15.8	31.7	63.4	126.7	15.8	31.7	63.4	126.7
83.2	23.6	47.2	94.4	188.8	17.7	35.4	70.8	141.6	15.8	31.6	62.8	126.0
8.0	2.0	3.5	5.0	8.0	2.0	3.5	5.0	8.0	2.0	3.5	5.0	8.0
2.0	.5	1.0	1.5	2.0	.5	1.0	1.5	2.0	.5	1.0	2.0	2.0
84.0	47.5	95.0	190.0	380.0	28.5	47.0	114.0	228.0	21.8	44.2	88.4	177.2
9.0	2.4	4.8	9.5	19.0	2.4	4.8	9.5	19.0	2.4	4.8	9.5	19.0
1.0	81.9	143.7	256.2	459.0	58.5	100.2	174.6	308.1	50.4	85.5	145.8	253.8
23.5	13.7	24.0	42.7	76.5	9.8	16.7	29.1	51.4	8.4	14.3	24.3	42.3
3.6	299.3	462.8	787.1	1,396.9	247.1	352.2	592.3	1,021.7	229.0	328.5	525.6	891.9
7.5	182.1	319.5	569.6	1,020.5	130.0	222.8	388.2	685.0	112.1	190.0	324.2	564.3
5.0	85.7	116.6	177.8	284.2	74.0	94.8	137.0	208.8	70.0	87.5	122.6	181.6
1.0	81.9	143.7	256.2	459.0	58.5	100.2	174.6	308.1	50.4	85.5	145.8	253.8
3.5	349.7	579.8	1,003.6	1,763.7	262.5	417.8	699.8	1,201.9	232.5	363.0	592.6	999.7
4.2	804.9	1,354.4	2,414.3	4,407.7	665.5	1,081.8	1,915.7	3,470.7	617.4	1,003.3	1,741.8	3,138.7
ollars per short ton of sulfur equivalent recovered												
7.	233.	196.	175.	160.	193.	157.	139.	126.	183.	148.	129.	116.
5.5	8.2	16.4	32.8	65.5	8.2	16.4	32.8	65.5	8.2	16.4	32.8	65.5
0.2	6.3	12.5	25.1	50.2	6.3	12.5	25.1	50.2	6.3	12.5	25.1	50.2
8.1	1.0	2.0	4.0	8.1	1.0	2.0	4.0	8.1	.7	1.5	2.9	5.9

The plant operates 24 hours per day,
330 days per year.

B

ASARCO REDUCTION PROCESS

Feed Gas Conditions	Units			
Sulfur oxides	% by volume, dry	4.26	4.26	4.2
Volume dry	1000 scfm	9.32	23.7	42.6
wet, diluted with air	1000 scfm	10.21	26.0	46.6
Total sulfur equivalent	tons per day	25.5	65.0	116.6
Capital Costs				
Installed equipment	$ thousands	1,150	2,476	3,950
Plant cost (factor 3.0)	$ thousands	3,500	7,430	12,000

These are estimated costs for the battery limits plant. Costs of offsite utilities, contingencies, working capital, inventory, interest, land, or plant access are not included.

*Installed equipment costs were estimated for this plant and the modified plant. The two other plants that handle the same volume of gas (26,000 scfm, wet and diluted with air) have the same capital costs. Costs for the remaining plants are in proportion to the 0.8 power of the volumes of gas handled.

**Modifi
omitte

Appendix B
Table B -5

EDUCTION PROCESS - CAPITAL COST ESTIMATES

4.26	4.26	6.32	6.32	6.32	6.32	8.38	8.38	8.38
23.7	42.6	9.24	23.7	23.7	42.5	8.4	21.3	38.1
26.0	46.6	10.12	26.0	26.0	46.5	9.2	23.5	42.7
65.0	116.6	37.5	96.5	96.5	172.7	45.0	114.5	205.2
476	3,950	1,150	2,476	**1,830	3,950	1,150	2,476	3,950
430	12,000	3,500	*7,430	**5,500	12,000	3,500	7,430	12,000

**Modified plant: final stage of reaction and collection omitted.

B

ASARCO REDUCTION PROCESS

		*Units			
Feed gas	sulfur dioxide	% by volume, dry	4.	4.	
	sulfur trioxide	% by volume, dry	.26	.26	
	oxygen	% by volume, dry	13.2	13.2	
Feed gas volume, dry		1000 scfm	9.32	23.7	
wet, diluted with air		1000 scfm	10.21	26.0	
Total sulfur equivalent in feed gas		tons per day	25.5	65.0	1
		1000 tons per year	8.4	21.4	
Sulfur production (95% recovery of total sulfur)		1000 tons per year	8.0	20.4	
Capital cost of plant (Ip)		$ millions	3.50	7.43	

Production Cost Items	Cost Basis			
A. Raw materials				
Feed gas		no cost		
Natural gas		included in fuel requiren		
B. Direct costs				
Labor (L)	$3.75/manhour	60.0	60.0	9
Supervision (S)	$4.75/manhour	9.5	9.5	
Payroll benefits	25% of (L + S)	17.4	17.4	2
Electricity	$10.0/megawatt-hr	26.6	61.9	11
Water	$0.20/1000 gal	13.3	14.2	2
Fuel: natural gas	$0.40/million Btu	155.9	397.0	71
Maintenance materials (M)	3.0% of Ip	105.0	222.8	36
Factory supplies	0.5% of Ip	17.5	37.1	6
Total direct costs		405.2	819.9	1,38
C. Indirect costs				
Depreciation	linear, 15-yr	233.3	495.2	80
Controllable indirect	0.50 (L + S + M)	87.2	146.2	22
Noncontrollable indirect	3.0% of Ip	105.0	222.8	36
Total indirect costs		425.5	864.2	1,38
Total Operating Cost fob plantsite	(A + B + C)	830.7	1,684.1	2,77
Operating cost, production of elemental sulfur		103.80	82.60	75

*All tons are short tons of 2000 pounds. Plant operate

**Final stage of reaction and collection omitted. (Reco

CTION PROCESS - OPERATING COST ESTIMATES

Appendix B
Table B-6

4.	4.	6.	6.	6.	6.	8.	8.	8.
.26	.26	.32	.32	.32	.32	.38	.38	.38
13.2	13.2	10.4	10.4	10.4	10.4	7.6	7.6	7.6
23.7	42.6	9.24	23.7	23.7	42.5	8.4	21.3	38.1
26.0	46.6	10.12	26.0	26.0	46.5	9.2	23.5	42.7
65.0	116.6	37.5	96.5	96.5	172.7	45.0	114.5	205.2
21.4	38.5	12.4	31.8	31.8	57.0	14.9	37.8	67.7
20.4	36.6	11.80	30.3	**27.1	54.1	14.1	35.9	64.4
7.43	12.0	3.50	7.43	**5.5	12.0	3.5	7.43	12.0

thousands of dollars per year

in fuel requirements

60.0	90.0	60.0	60.0	60.0	90.0	60.0	60.0	90.0
9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5
17.4	24.9	17.4	17.4	17.4	24.9	17.4	17.4	24.9
61.9	110.5	26.6	61.9	45.2	110.5	26.6	61.9	110.5
14.2	21.6	13.3	14.2	14.2	21.6	13.3	14.2	21.6
397.0	712.2	148.2	380.8	380.8	681.8	152.7	387.8	694.8
222.8	360.0	105.0	222.8	165.0	360.0	105.0	222.8	360.0
37.1	60.0	17.5	37.1	27.5	60.0	17.5	37.1	60.0
819.9	1,388.7	397.5	803.7	719.6	1,358.3	402.0	810.7	1,371.3
495.2	800.0	233.3	495.2	366.7	800.0	233.3	495.2	800.0
146.2	229.8	87.2	146.2	117.3	229.8	87.2	146.2	229.8
222.8	360.0	105.0	222.8	165.0	360.0	105.0	222.8	360.0
864.2	1,389.8	425.5	864.2	649.0	1,389.8	425.5	864.2	1,389.8
,684.1	2,778.5	823.0	1,667.9	1,368.6	2,748.1	827.5	1,674.9	2,761.1

dollars per short ton

82.60	75.90	69.80	55.00	50.50	50.80	58.70	46.60	42.90

. Plant operates 330 days per year.

omitted. (Recovery of sulfur lowered to 85%)

B

LIME AND LIMESTONE WET-SCRUBBING PROCESS

Offgas Sulfur				
Sulfur equivalent in offgas, tons/day	50	50	50	
Sulfur oxides in offgas, volume %	1	4	9	
Lime-Burning Section				
Major equipment, $	652,000	652,000	652,000	
Plant cost (factor 2.5), $	1,630,000(1)	1,630,000	1,630,000	
Limestone Fine-grinding Section				
Major equipment, $	144,400	144,400	144,400	
Plant cost (factor 3.63), $	524,000(1)	524,000	524,000	
Scrubber and Waste Treatment				
Gas flow, acfm	168,000	42,000	18,700	
Plant cost, (excluding fans), $	460,000	152,000	79,000	1
Fans, installed cost (factor 2.0), $	64,000(1)	17,000	9,000	
Plant cost, with fans $	524,000	169,000	88,000	1

Note (1) A factor of 2.5 was selected for lime burning as the major equipment is heavily weighted by one item, the kiln, which is relatively easy to install. Also, a lime plant needs little in utilities, buildings, instrumentation etc. These considerations are even more pronounced for the fans, and hence a factor of 2.0 was selected for them.

The limestone fine-grinding section is more complex and the factor of 3.63 is appropriate for a plant handling both solids and liquids.

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CRUBBING PROCESSES - CAPITAL COST ESTIMATES

Appendix B
Table B-7

50	148(2)	148	148	1,000	1,000	1,000
9	1	4	9	1	4	9
652,000	1,190,000	1,190,000	1,190,000	8,200,000	8,200,000	8,200,000
1,630,000	2,970,000	2,970,000	2,970,000	20,500,000	20,500,000	20,500,000
144,400	303,400	303,400	303,400	1,607,000	1,607,000	1,607,000
524,000	1,100,000	1,100,000	1,100,000	5,830,000	5,830,000	5,830,000
18,700	497,000	124,000	55,400	3,360,000	840,000	374,000
79,000	1,090,000	360,000	189,000	5,040,000	1,653,000	868,000
9,000	128,000	52,000	22,000	1,024,000	268,000	126,000
88,000	1,218,000	412,000	211,000	6,064,000	1,921,000	994,000

(2) A quantity of 148 tons per day of sulfur was selected because this quantity uses the output of one large lime kiln, or 285 tons of quicklime. Plants to treat larger flows of sulfur oxides require multiple lime kilns.

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LIME WET-SCRUBBING PROCESS - LIME-BURNING SECTION - OPERATING C

	Units	
Sulfur equivalent in feed gas	tons per day	50
	1000 tons per year	16.5
Calcium oxide produced	tons per day	96
	1000 tons per year	32
Capital cost (Ip)	$ million	1.63

Production Cost Items	Cost Basis	thousan p
A. Raw materials		
Feed gas	no cost	
Limestone	variable cost	171.0
B. Direct costs		
Labor (L)	$3.75/manhour	30.0
Supervision (S)	$4.75/manhour	9.5
Payroll benefits	25% of (L + S)	9.9
Steam	allowance	1.0
Electricity	$10.0/megawatt-hr	29.5
Air	allowance	1.0
Process water	allowance	.5
Fuel	$0.40/million Btu	108.8
Maintenance materials (M)	3.0% of Ip	48.9
Factory supplies	0.5% of Ip	8.2
Laboratory	allowance	.5
Total direct costs		247.8
C. Indirect costs		
Depreciation	linear, 15-yr	108.7
Controllable indirect	0.50 (L + S + M)	44.2
Noncontrollable indirect	3.0% of Ip	48.9
Total indirect costs		201.8
Total operating cost	(A + B + C)	620.6

	dollars p of sulfur
Operating cost, based on sulfur oxides in feed gas	37.60

The cost estimate is based on using 110% of the stoichiometric quantity of lime needed to absorb all the sulfur oxides. The plant operates 24 hours per day, 330 days per year.

Costs of disposal of the byproduct calcium sulfite/sulfate, as well as the costs of plant water, have been charged to the wet-scrubbing and waste disposal section. All tons

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Appendix B
Table B - 8

ME WET-SCRUBBING PROCESS - LIME-BURNING SECTION - OPERATING COST ESTIMATES

	Units			
eed gas	tons per day	50	148	1,000
	1000 tons per year	16.5	48.8	330
	tons per day	96	285	1,920
	1000 tons per year	32	94	634
	$ million	1.63	2.97	20.5
		thousands of dollars per year		
	Cost Basis			
	no cost			
	variable cost	171.0	504.0	2,850.0
	$3.75/manhour	30.0	30.0	240.0
	$4.75/manhour	9.5	9.5	9.5
	25% of (L + S)	9.9	9.9	62.4
	allowance	1.0	1.5	11.0
	$10.0/megawatt-hr	29.5	64.9	501.5
	allowance	1.0	1.5	11.0
	allowance	.5	1.0	5.0
	$0.40/million Btu	108.8	320.0	2,176.0
ials (M)	3.0% of Ip	48.9	89.1	615.0
	0.5% of Ip	8.2	14.9	102.5
	allowance	.5	1.0	5.0
s		247.8	543.3	3,738.9
ect	linear, 15-yr	108.7	198.1	1,367.4
direct	0.50 (L + S + M)	44.2	64.3	432.3
ts	3.0% of Ip	48.9	89.1	615.0
		201.8	351.5	2,414.7
	(A + B + C)	620.6	1,398.8	9,003.6
		dollars per short ton of sulfur equivalent		
sulfur oxides in feed gas		37.60	28.60	27.30

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s per year.

Costs of disposal of the byproduct calcium sulfite/sulfate, as well as the costs of plant water, have been charged to the wet-scrubbing and waste disposal section. All tons are short tons of 2000 pounds. No allowance was made for contingency, land, or working capital when estimating capital costs. Utilities are assumed to be available.

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LIMESTONE WET-SCRUBBING PROCESS - LIMESTONE FINE-GRINDING SECTION - OPERA

	Units	
Sulfur equivalent in feed gas	tons per day	50
	1000 tons per year	16.5
Limestone processed	tons per day	235
	1000 tons per year	77.6
Capital cost of plant (Ip)	$ thousands	524.0

Production Cost Items	Cost Basis	thousa p
A. Raw materials		
Limestone	variable	232.8
B. Direct costs		
Labor (L)	$3.75/manhour	30.0
Supervision (S)	$4.75/manhour	9.5
Payroll benefits	25% of (L + S)	9.9
Steam	allowance	1.0
Electricity	$10.0 per megawatt-hr	22.6
Air	allowance	1.0
Process water	allowance	.5
Maintenance materials (M)	3.0% of Ip	15.7
Factory supplies	0.5% of Ip	2.6
Laboratory	allowance	.5
Total direct costs		93.3
C. Indirect costs		
Depreciation	linear, 15-yr	35.0
Controllable indirect	0.50 (L + S + M)	27.6
Noncontrollable indirect	3% of Ip	15.7
Total indirect costs		78.3
Total operating cost	(A + B + C)	404.4

	dollars of sulfu
Operating cost, based on sulfur oxides in feed gas	24.50

The cost estimate is based on using 150% of the stoichiometric quantity of limestone needed to absorb all the sulfur oxides. The plant operates 24 hours per day, 330 days per year.

Costs of disposal of the byproduct calcium sulfite/sulfate, as well as the costs of plant water, have been charged to the wet-scrubbing and waste-treating section. All tons

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Appendix B
Table B-9

NE WET-SCRUBBING PROCESS - LIMESTONE FINE-GRINDING SECTION - OPERATING COST ESTIMATES

	Units			
in feed gas	tons per day	50	148	1,000
	1000 tons per year	16.5	48.8	330.0
d	tons per day	235	695	4,700
	1000 tons per year	77.6	230.0	1,551.0
ant (Ip)	$ thousands	524.0	1,100.0	5,830.0
		thousands of dollars per year		
ems	Cost Basis			
	variable	232.8	667.0	3,877.5
	$3.75/manhour	30.0	30.0	60.0
(S)	$4.75/manhour	9.5	9.5	9.5
fits	25% of (L + S)	9.9	9.9	17.4
	allowance	1.0	1.5	11.0
	$10.0 per megawatt-hr	22.6	64.8	461.0
	allowance	1.0	1.5	11.0
	allowance	.5	1.0	5.0
aterials (M)	3.0% of Ip	15.7	33.0	175.0
ies	0.5% of Ip	2.6	5.5	29.2
	allowance	.5	1.0	5.0
costs		93.3	157.7	784.1
	linear, 15-yr	35.0	73.4	388.9
indirect	0.50 (L + S + M)	27.6	36.3	122.3
ie indirect	3% of Ip	15.7	33.0	175.0
t costs		78.3	142.7	686.2
t	(A + B + C)	404.4	967.4	5,347.8
		dollars per short ton of sulfur equivalent		
d on sulfur oxides in feed gas		24.50	19.80	16.20

based on using
metric quantity
to absorb all the
plant operates
0 days per year.

Costs of disposal of the byproduct calcium sulfite/sulfate, as well as the costs of plant water, have been charged to the wet-scrubbing and waste-treating section. All tons are short tons of 2000 pounds. No allowance was made for contingency or working capital when estimating the capital cost. Utilities have been assumed to be available.

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